REPORT

2019 Bruce Head Shore-based Monitoring Program

Mary River Project, Baffin Island, Nunavut

Submitted to:

Baffinland Iron Mines Corporation

2275 Upper Middle Road East - Suite 300
Oakville, Ontario

Submitted by:

Golder Associates Ltd.

2nd floor, 3795 Carey Road, Victoria, British Columbia, V8Z 6T8, Canada

+1 250 881 7372

1663724-199-R-Rev0-23000

3 September 2020

Executive Summary

The Mary River Project (hereafter, “the Project”) is an operating open pit iron ore mine owned by Baffinland Iron Mines Corporation (Baffinland) and located in the Qikiqtani Region of North Baffin Island, Nunavut. To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is currently authorized to transport 6.0 million tonnes per annum (Mtpa) of iron ore to global markets. The operating mine site is connected to Milne Port, located at the head of Milne Inlet, through which iron ore is transported to chartered ore carrier vessels for open water shipping along the Project’s Northern Shipping Route. During the first year of ERP operations in 2015, Baffinland shipped ~900,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached ~4.2 million tonnes involving 56 return ore carrier voyages. A total of 5.44 Mtpa of iron ore was shipped via 71 return voyages in 2018 and 5.86 Mtpa of ore was shipped via 81 return voyages in 2019.

The Project’s Northern Shipping Route encompasses Milne Inlet, Eclipse Sound, Pond Inlet, and adjacent water bodies. This coastal fjord system represents important summering grounds for narwhal (*Monodon monoceros*) in the Canadian Arctic. Therefore, to investigate narwhal response to shipping activities along the Northern Shipping Route, the Bruce Head Shore-based Monitoring Program (“the Program”) has been conducted annually since 2014, following a pilot project in 2013. The Program was structured to specifically address Project Certificate (PC) conditions 99c, 101g, 109, and 111, related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal abundance, distribution, and migratory movements within the Project’s Regional Study Area (RSA). The 2019 shore-based Program represents the fifth year of environmental effects monitoring undertaken at Bruce Head in support of the Project.

This report presents the results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet during the 2014 - 2017 and 2019 open-water seasons. Behavioural response of narwhal to Project-related ore carriers and other non-Project-related vessel traffic was investigated by collecting visual survey data from a cliff-based observation platform at Bruce Head, overlooking the Northern Shipping Route. As knowledge regarding the context and function (if any) of narwhal aggregations and space use patterns is generally incomplete, monitoring of narwhal relative abundance, distribution, and group composition is warranted to better understand potential responses to a perceived threat (i.e. a transiting vessel). Therefore, information was collected on relative abundance and distribution (RAD), group composition, and behaviour of narwhal near Bruce Head. Additional data were collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

The following is a summary of key findings pertaining to narwhal behavioural response to vessel traffic based on five years of shore-based visual survey data collected at Bruce Head between 2014 and 2019:

Relative Abundance and Distribution

- The overall relative abundance of narwhal in the Stratified Study Area (SSA), inferred from sighting rate (no. of narwhal per hour - corrected for effort), has remained relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. **Narwhal numbers in the SSA were shown to be comparable to baseline levels documented during the 2014 Bruce Head Monitoring Program, which took place prior to the start of iron ore shipping, noting**

however that some level of shipping activity still occurred through the SSA during 2014 (e.g., five Project support vessels and 13 non-Project-related vessels). These findings are consistent with results from Baffinland's other narwhal monitoring programs demonstrating that the Bruce Head area continues to support high narwhal densities and proportionately higher habitat use by narwhal compared to other areas in the broader Regional Study Area (RSA; Elliott et al. 2015; Thomas et al. 2015; Golder 2020a; Golder 2020b).

Within each study year, a likely but uncertain effect of vessel exposure on narwhal relative abundance in the SSA was observed. Specifically, vessel exposure was shown to result in a significant decrease in narwhal sightings in the SSA compared to when no vessels were present, but only when narwhal were exposed to vessels travelling north and away from the study area, and only at close exposure distances of 2-3 km. **These results suggest that the relative abundance of narwhal is influenced by vessel traffic at close distances, although the exact spatial extent of this effect could not be determined due to high data variability.**

Group Composition and Behaviour

- Group Size: None of the effects of shipping (distance from vessel, vessel direction, vessel orientation relative to the Behavioural Study Area or BSA) on narwhal group size were shown to be statistically significant ($P>0.2$ for all effects). **These results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure.**
- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the five sampling years. The daily proportion of calves and/or yearlings recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2019 (annual mean of 11.2%) than all previous years (2014=10.7%, 2016=9.7%, 2017=7.7%), with the exception of 2015 (14%). This suggests that calving success at Bruce Head in 2019 is consistent with pre-shipping levels, despite year-over-year increases in shipping in the BSA.
  - Vessel traffic was shown to have a significant effect on group composition relative to the probability of calf/yearling presence (i.e., a significant interaction was observed between 'vessel distance', 'vessel direction' and 'vessel orientation relative to BSA'). Results suggest that the proportion of groups with calves/yearlings was similar between all four vessel traffic scenarios (i.e., vessel transiting toward/away BSA, vessel transiting southbound/northbound), but generally increased during close vessel encounters. This finding may suggest that groups with calves/yearlings may be less inclined to maneuver out of the way of transiting vessels at close distances, though it is unclear whether this effect was significant. Further assessment of the relative proportion of strictly mature groups (i.e. groups possessing no calves or yearlings) during close vessel encounters should be carried out in future analyses for comparison.
  - **Collectively, these results suggest that narwhal group composition did not significantly change between study years despite an increase in shipping activity during this period, but the proportion of groups with calves/yearlings was generally higher during close vessel encounters.**
- Group Spread: Narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. In general, group spread did not significantly change during vessel-exposure events. However, loosely spread groups were less common when vessels headed away from the BSA (32% for northbound vessels and 30% for southbound vessels)

than when vessels were heading toward the BSA (38% for northbound vessels and 32% for southbound vessels). **These results suggest that narwhal group spread did not significantly change during vessel exposure events.**

- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. A possible but uncertain effect of vessel distance on narwhal group formation was evident that depended on vessel direction, with the most consistent effect suggested for southbound vessels moving away from the BSA. However, none of the shipping-related variables were statistically significant. **These results suggest that narwhal group formation did not significantly change in the BSA during vessel exposure events.**
- Group Direction: Vessel traffic was shown to have a significant effect on travel of narwhal groups in the BSA (i.e., a significant interaction was observed between 'vessel distance', 'vessel direction' and 'vessel orientation relative to BSA' although the effect on travel direction was shown to be variable). Narwhal groups were predominantly observed traveling south through the BSA. Southbound travel was least common when southbound vessels were headed away from the BSA, and most common when northbound vessels were headed away from the BSA. **These findings suggest that narwhal groups may experience some level of avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid "following" vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels.**
- Travel Speed: The majority of the observed narwhal groups travelled at a medium speed, regardless of vessel exposure conditions. A lack of statistical significance of any of the vessel-related variables suggests that vessel traffic did not have an effect on narwhal groups decreasing their travel speed. The nature of the data for fast-travelling groups was not adequate to test for the effect of vessel exposure on increased travel speed in the BSA. **These results suggest that narwhal did not decrease their travel speed or demonstrate a 'freeze' response during vessel exposure events as they've shown to do during encounters with other perceived threats (i.e. killer whales).**
- Distance from Bruce Head Shore: Narwhal groups were observed more often within 300 m of the Bruce Head shore under both vessel presence and vessel absence scenarios. Offshore groups (>300 m) were detected less frequently with increasing Beaufort scale values, suggesting a decreased detection ability at distance with deteriorating sea state. Furthermore, vessel traffic was shown to result in a significant decrease in 'distance from shore' (i.e., significant interaction was between 'vessel distance', 'vessel direction' and 'vessel orientation). This effect appeared to be largely attributed to vessel traffic moving toward the BSA. **The results suggest that narwhal swim closer to shore when in close proximity to vessels moving toward the BSA.**

Overall, results from this five-year shore-based monitoring study support impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that ship noise effects on narwhal will be limited to localized avoidance behaviour, consistent with low to moderate severity responses (Southall et al. 2007; Finneran et al. 2017). No evidence was observed of large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a non-significant effect used in the FEIS).

ᐃᓱᒪᑕᐅᓂᕐᓂᑦ ᓇᐃᓈᖅᓯᒪᔪᖅ

ᓄᓘᔮᓂᑦ ᐱᓕᕆᐊᖅ (ᑖᒡᑯᓂ ᑕᐃᔭᐅᔪᖅ, “ᐱᓕᕆᐊᖅ”) ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᒥᑦ ᓴᕕᖕᒥᑦ ᐅᔭᕋᖅᑕᖅᑎᐅᔪᑦ ᓇᖏᓂᕆᔭᐅᑉᓗᓂ ᐹᕕᓐᓛᓐ ᓴᕕᖕᓄᑦ ᐅᔭᕋᒃᑕᕆᐊᓕᕆᔩᒃᑯᑦ (ᐹᕕᓐᓛᓐᑯᑦ) ᕿᑭᖅᑖᓘᖕᒥᑦᑐᖅ ᐅᐊᖕᓇᖕᓂᑦ ᕿᑭᖅᑖᓘᒃ, ᓄᓇᕗᑦ. ᐅᑉᓗᒥᒧᑦ ᑎᔅᓗᒍ ᐹᕕᓐᓛᓐᑯᑦ ᐊᐅᓛᕐᓂᖃᖅᑐᑦ ᐱᒋᐊᓵᕐᓂᕐᒥᑦ ᑮᓇᐅᔭᓕᐅᕐᓂᕐᒧᑦ (ERP) ᒫᓐᓇᐅᔪᕐᓗ ᓈᒻᒥᒋᔭᐅᓯᒪᔪᖅ ᐊᒻᔭᖅᑐᐃᓂᐊᕐᓗᑎᒃ 6.0 ᒥᓕᔭᓐ ᑖᓐᓂᒃ ᐊᕐᕌᒍᑕᒫᒃᑯᑦ (Mtpa) ᓴᕕᖕᓂᑦ ᓄᓇᕐᔪᐊᕐᒥᑦ ᓂᐅᕕᐊᒃᓴᓕᖕᓄᑦ. ᐊᐅᓛᖅᑎᑕᐅᔪᖅ ᐅᔭᕋᒃᑕᕆᐊᖅ ᐊᒃᑐᐊᓂᖃᖅᑐᖅ ᕿᙳᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒧᑦ, ᕿᙳᐊᓃᔅᓗᓂ, ᑕᐃᑰᓇ ᓴᕖᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᒻᔭᖅᑕᐅᖃᑦᑕᖅᖢᑎᒃ ᑦᓵᑕᐅᔪᒃᑯᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᖃᑦᑕᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐊᐅᔭᐅᑎᓕᓗᒍ ᐱᓕᐱᐊᕐᒧᑦ ᐅᐊᖕᓇᖅᐸᓯᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕿᑎᖓᒍᑦ. ᓯᕗᓪᓕᕐᒥᑦ ᐅᑭᐅᕐᒥᑦ ᐱᒋᐊᓵᕐᓂᕐᒥᑦ ᑮᓇᐅᔭᓕᐅᕐᓂᕐᒧᑦ (ERP) ᐊᐅᓛᖅᑎᑦᑎᓃᑦ 2015-ᒥᑦ, ᐹᕕᓐᓛᓐᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᓚᐅᖅᑐᑦ ~900,000 ᑖᓐᓂᒃ ᓴᕕᖕᓂᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᑦ ᕿᙳᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒥᑦ 13-ᓂᒃ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᑉᓗᑎᒃ ᐅᑎᕈᔾᔨᓚᐅᖅᑐᑦ. 2017-ᒥᑦ, ᑲᑎᔅᓗᒋᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ ᕿᙳᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒥᑦ ᑎᑭᐅᑎᓚᐅᖅᑐᑦ ~4.2 ᒥᓕᔭᓐ ᑖᓐᓄᑦ 56-ᓂᒃ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᑉᓗᑎᒃ ᐅᑎᕈᔾᔨᓚᐅᖅᑐᑦ. ᑲᑎᔅᓗᒋᑦ 5.44 Mtpa ᓴᕖᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᓚᐅᖅᑐᑦ 71-ᓂᒃ 2018-ᒥᑦ ᐊᒻᒪᓗ 5.86 Mtpa ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᑉᓗᑎᒃ 81-ᓂᒃ 2019-ᒥᑦ.

ᐱᓕᕆᐊᑉ ᐅᐊᖕᓇᖅᐸᓯᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕿᑎᖓ ᐊᕙᓗᓯᒪᔪᖅ ᕿᒻᒧᐊ, ᑕᓯᐅᔭᖅ, ᒥᑦᑎᒪᑕᓕᒃ, ᐊᒻᒪᓗ ᐊᑭᐊᓃᑦᑐᑦ ᐃᒪᖅᑲᕐᓂᐅᔪᑦ. ᑕᒪᓐᓇ ᓯᓪᔭᒧᑦ ᖃᓂᖕᓂᖅ ᐱᓪᓚᕆᐅᕆᔭᐅᔪᖅ ᐊᐅᔭᒃᑯᑦ ᑑᒑᓕᖕᓄᑦ ᑲᓇᑕᒥᑦ ᐅᑭᐅᖅᑕᖅᑐᒥᑦ. ᑕᐃᒪᓐᓇᒧᑦ, ᖃᐅᔨᓴᐃᓂᐊᕐᓗᓂ ᑑᒑᓖᑦ ᐅᐸᓗᐊᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ ᐅᐊᖕᓇᖅᐸᓯᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕿᑎᖓᓂᑦ, ᐃᓗᓯᓕᖕᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᑐᕌᖓᔪᖅ (“ᑐᕌᖓᔪᖅ”) ᖃᐅᔨᓴᐃᖃᑦᑕᖅᑐᖅ ᐊᕐᕌᒍᑕᒫᒃᑯᑦ 2014-ᒥᑦ ᐱᒋᐊᖅᖢᑎᒃ, ᑭᖑᓂᐊᒍᑦ ᐆᒃᑐᕋᐅᑎᖃᖅᑳᖅᖢᑎᒃ ᐱᓕᕆᐊᕐᒥᑦ 2013-ᒥᑦ. ᑐᕌᖓᔪᖅ ᐋᖅᑭᒋᐊᖅᑕᐅᓯᒪᔪᖅ ᐱᓕᕆᐊᕆᓂᐊᕐᓗᒋᑦ ᐱᓕᕆᐊᕐᒧᑦ ᓇᓗᓇᐃᒃᑯᑕᕐᒥᑦ ᖃᓄᐃᖓᔭᕆᐊᖃᕐᓂᐅᔪᑦ 99c, 101g, 109, ᐊᒻᒪᓗ 111, ᕿᒥᕐᕈᓗᒋᑦ ᐃᓱᐃᓵᕆᓂᐅᔪᖕᓇᖅᑐᑦ ᑕᕆᐅᕐᒥᐅᑕᓄᑦ ᐅᒥᐊᔪᐊᓂᒃ ᐱᔪᓂᒃ ᐊᓯᐊᒻᒍᖅᑎᑦᑐᐃᓐᓇᕆᐊᖅᖢᑎᒃ ᓂᕐᔪᐃᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ, ᓇᒧᙵᐅᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᐅᑎᖅᑕᕐᓂᕆᖃᑦᑕᖅᑕᖅᑎᖏᓐᓄᑦ ᐱᓕᕆᐊᑉ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᖓᓐᓂᑦᑐᓂᑦ (RSA). 2019-ᒥᑦ ᓯᕗᓪᓕᒻᒥᐅᖓᔪᒥᑦ ᑕᓪᓕᒪᖓᓂᑦ ᐅᑭᐅᕐᒥᑦ ᐊᕙᑎᒧᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᓄᑦ ᖃᐅᔨᓴᐃᓂᖃᓚᐅᖅᑐᑦ ᐃᓗᓯᓕᖕᒥᑦ ᐃᑲᔪᖅᖢᒍ ᐱᓕᕆᐊᖅ.

ᑖᓐᓇ ᐅᓂᑉᑳᖅ ᑐᓂᓯᔪᖅ ᖃᓄᐃᖓᓂᐅᔪᓂᒃ ᐃᒪᕐᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ ᑑᒑᓕᖕᓂᑦ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔾᔪᓂᖏᓐᓂᑦ ᕿᙳᐊᓂᑦ 2014-ᒥᑦ 2017-ᒧᑦ ᐊᒻᒪᓗ 2019-ᒥᑦ ᐊᐅᔭᐅᑎᓪᓗᒍ. ᐱᖅᑯᓯᖏᓐᓄᑦ ᐅᐸᓗᐊᓂᕐᒥᑦ ᑑᒑᓖᑦ ᐱᓕᕆᐊᕐᒧᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᖃᑦᑕᖅᑐᓄᑦ ᐅᒥᐊᕐᔪᐊᓄᓪᓗ ᐱᓕᕆᐊᕐᒨᖓᙱᑦᑐᑦ ᐃᖏᕐᕋᔾᔪᓐᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᖅ ᐃᓗᓯᓕᖕᒥᑦ ᐃᓪᓈᕈᓯᒥᔅᓗᑎᒃ ᑕᐅᑐᒃᓗᒋᑦ ᑲᑎᖅᓱᐃᑉᓗᑎᒃ ᓈᓴᐅᑎᓂᒃ/ᑎᑎᖅᑲᓂᒃ, ᑕᑯᒃᓴᐅᔪᖅ ᐅᐊᖕᓇᖅᐸᓯᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕿᑎᖓᓄᑦ. ᖃᐅᔨᒪᓂᖅ ᐱᔾᔪᑎᒋᑉᓗᒍ ᑑᒑᓖᑦ ᑲᑎᖅᑲᑦᑕᕐᓂᖏᑦ ᐊᒻᒪᓗ ᐃᓂᐅᔪᒥᑦ ᐊᑐᖅᑲᑦᑕᕐᓂᖏᓐᓄᑦ ᖃᓄᐃᓕᐅᕐᓂᐅᔪᓄᑦ ᐱᐊᓂᒃᓯᒪᙱᑦᑐᖅ, ᖃᐅᔨᓴᐃᓂᖅ ᑑᒑᓖᑦ ᐊᒥᓲᓂᖏᓐᓂᒃ, ᓇᒧᙵᐅᓂᖏᑦ, ᐊᒻᒪᓗ ᑲᑎᒪᓂᖏᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᑐᑭᓯᐊᓂᐊᕐᓗᒋᑦ ᐅᐸᓗᐊᓂᓇᔪᓐᓇᖅᑕᖏᑦ ᐅᓗᕆᐊᓇᕐᓂᖅᑭᑕᐅᓇᓯᒋᔪᓄᑦ (ᓲᕐᓗ, ᐃᖏᕐᕋᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ). ᑕᐃᒪᓐᓇᒧᑦ, ᑐᑭᓯᐅᒪᔾᔪᑏᑦ ᑲᑎᑕᐅᔪᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᓇᒧᙵᐅᓂᖏᓐᓄᑦ, ᑲᑎᒪᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᐱᖅᑯᓯᖏᓐᓄᑦ ᑑᒑᓖᑦ ᖃᓂᑕᖓᓃᑦᑐᑦ ᐃᓗᐊᓕᑕᐅᑉ. ᓈᓴᐅᑎᒃᑲᓐᓂᑦ/ᑎᑎᖅᑲᐅᑎᒃᑲᓐᓂᑦ ᑲᑎᑕᐅᔪᑦ ᐊᕙᑎᐅᑉ ᖃᓄᐃᖓᓂᖓᓄᑦ ᐊᒻᒪᓗ ᐃᓄᐃᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ (ᓲᕐᓗ ᐅᒥᐊᕐᔪᐊᑦ ᐊᒻᒪᓗ ᒪᖃᐃᖃᑦᑕᖅᑐᑦ) ᖃᐅᔨᓂᐊᕐᓗᒋᑦ ᐊᑯᓐᓂᖏᓐᓂᑦ ᖃᓄᐃᓕᖅᑎᑦᑎᓂᐅᔪᓐᓇᖅᑐᑦ ᐱᓕᕆᐊᕐᒥᑦ ᐅᒥᐊᕐᔪᐊᓂᒃ ᑎᑭᑎᑦᑎᑲᑦᑕᕐᓂᐅᔪᓄᑦ ᐊᒻᒪᓗ ᐱᔾᔪᑕᐅᔪᓐᓇᖅᑐᑦ ᑑᒑᓖᑦ ᐱᖅᑯᓯᕆᔭᖏᓐᓄᑦ.

ᐅᓇ ᓇᐃᓈᖅᓯᒪᔪᖅ ᖃᐅᔨᔭᐅᔪᓂᒃ ᑑᒑᓖᑦ ᐱᖅᑯᓯᖏᑦ ᐅᐸᓗᐊᓂᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐅᑭᐅᓂᑦ ᑕᓪᓕᒪᓂᑦ ᐃᒪᕐᒥᑦ ᑕᐅᑐᒃᓱᑎᒃ ᖃᐅᔨᓴᐃᑉᓗᑎᒃ ᑲᑎᑕᐅᔪᑦ ᐃᓗᐊᓕᕐᒥᑦ ᐊᑯᓐᓂᖏᓐᓂᑦ 2014 ᐊᒻᒪᓗ 2019:

ᐊᒥᓲᓂᖏᑦ ᐊᒻᒪᓗ ᓇᒧᙵᐅᖃᑦᑕᕐᓂᖏᑦ

- ᑕᒪᓗᒃᑖᕐᒧᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᑑᒑᓖᑦ ᐃᒪᕐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (SSA), ᑕᑯᔭᐅᔪᓂᑦ ᓈᓴᐅᑎᓂᑦ (ᖃᑉᓯᐅᓂᖏᑦ ᑑᒑᓖᑦ ᐃᑲᕐᕋᑕᒪᒃᑯᑦ - ᐋᖅᑭᒋᐊᖅᑕᐅᔪᖅ ᐱᓇᓯᖕᓂᕐᒧᑦ), ᓱᕐᑯᓯᐊᓗᐊᖅᓯᒪᙱᑦᑐᑦ ᐊᑯᓐᓂᖏᓐᓂᑦ 2014 ᐊᒻᒪᓗ 2019 ᐊᒥᓱᙳᖅᐸᓪᓕᐊᓚᓗᐊᖅᑎᓪᓗᒋᑦ ᓴᕕᖕᓂᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᒥᐊᕐᔪᐊᒃᑯ ᐅᐊᖕᓇᖅᐸᓯᒃᑯᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕿᑎᖓᓄᑦ ᑖᑉᑯᓇᓂ ᐅᑭᐅᕐᓂ. **ᑑᒑᓖᑦ ᖃᑉᓯᐅᓂᖏᑦ SSA-ᒥᑦ ᑕᑯᒃᓴᑎᑕᐅᔪᑦ ᖃᓄᐃᓐᓂᖅᓴᐅᓂᖏᓐᓅᕐᓂᐊᕐᓗᒋᑦ ᑭᓪᓕᐅᔪᑦ ᓇᓄᓐᓂᕆᔭᖏᓐᓄᑦ ᑎᑎᕋᐅᓯᐅᓯᒪᔪᑦ 2014-ᒥᑦ ᐃᓗᓯᓕᖕᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ, ᖃᐅᔨᓴᐃᓂᖃᓚᐅᖅᑐᖅ ᓴᕕᖕᓂᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᐊᖅᑎᓪᓗᒍ, ᑭᓯᐊᓂ**

ᖃᐅᔨᓴᐅᖅᑐᑦ ᐃᓚᖏᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓃᑦ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᑕᐃᒪᐅᖃᑦᑕᓚᐅᖅᑐᑦ SSA-ᑯᑦ 2014-ᒥᑦ (ᓲᕐᓗ, ᑕᓪᓕᒪᐃᑦ ᐱᓕᕆᐊᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᒻᒪᓗ 13 ᐱᓕᕆᐊᕐᒨᖏᑦᑐᖅ ᐅᒥᐊᕐᔪᐊᑦ). ᑕᒪᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᐊᔾᔨᒋᔭᖏᑦ ᖃᓄᐃᖓᓂᐅᔪᓄᑦ ᐸᕝᕙᓛᓐᑯᑦ ᐊᓯᖏᓐᓄᑦ ᑑᒑᓕᖕᓂᒃ ᖃᐅᔨᓴᐃᓂᕆᔭᖏᓐᓄᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᑦ ᐃᓄᕕᓕᐅᑉ ᖃᓂᑕᖏᓐᓂᑦ ᑑᒑᓕᒃᑕᖃᐅᕐᒪᑦ ᐊᒻᒪᓗ ᖁᑦᑎᖕᓂᖅᓴᓂᒃ ᐃᓂᖃᕐᕕᖃᖅᓱᑎᒃ ᑕᐅᑐᖕᒫᖅᓱᒋᑦ ᐊᓯᖏᑦ ᐃᓂᐅᔪᑦ ᐊᖏᓂᖅᓴᐅᔪᒥᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA; Elliott et al. 2015; Thomas et al. 2015; Golder 2020a; Golder 2020b).

ᐊᑐᓂ ᖃᐅᔨᓴᐃᓂᕐᓂᑦ, ᓇᓗᓇᖅᑐᖃᑐᐃᓐᓇᕆᐊᓕᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᓂᒃ ᐅᒥᐊᕐᔪᐊᕐᓂᑦ ᑑᒑᓕᖕᓄᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ SSA-ᒥᑦ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᑦ. ᐱᓗᐊᖅᑐᒥᑦ, ᐅᒥᐊᕐᔪᐊᖅᑕᖃᕐᓂᐅᔪᓂᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᖅ ᒥᒃᓴᕚᓪᓕᕐᔪᐊᕐᓂᖏᑦ ᑑᒑᓖᑦ ᑕᑯᔭᐅᔪᑦ SSA-ᒥᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑦᑐᓂᐅᖕᒪᓂᑦ, ᑭᓯᐊᓂ ᑑᒑᓖᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᖑᔪᓄᑦ ᖃᓂᑦᑕᕿᖕᒪᑕ ᐅᐊᖕᓇᒧᑦ ᐊᒻᒪᓗ ᕿᒪᒃᐸᓪᓕᐊᑉᐳᒍ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᖅ, ᐊᒻᒪᓗ ᖃᓂᓐᓂᖃᕿᖕᒪᑕ 2-3 ᑭᓛᒥᑕᓂᒃ ᐅᖓᓯᒃᑎᒋᔪᒥᑦ. **ᖃᓄᖕᒪᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᐊᒥᓲᓂᖏᑦ ᑑᒑᓖᑦ ᐱᔪᑎᖃᖅᑐᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᓂᖏᑦ ᖃᓂᒃᑳᖕᒪᑕ ᑑᒑᓕᖕᓄᑦ, ᖃᓄᓪᓚᑖᖅ ᐅᖓᓯᒃᑎᒋᓂᐅᔪᖅ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᒧᑦ ᖃᐅᔨᔭᐅᓂᖅ ᐊᔪᓚᐅᖅᑐᖅ ᓈᓴᐅᑎᓂᑦ/ᑎᑎᖅᑲᓂᒃ ᐊᔾᔨᒌᙱᓐᓂᐅᓗᐊᖅᑐᓄᑦ.**

ᑲᑎᔪᑦ ᐊᒻᒪᓗ ᐱᖁᓯᖏᑦ

- ᑲᑎᕐᒪᔪᑦ ᐊᒥᓲᓂᖏᑦ: ᓇᓕᑐᐃᓐᓇᖏᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ (ᐅᖓᓯᒃᑎᒋᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᓂᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓇᒧᙵᐅᓂᖏᑦ ᐱᖁᓯᕆᔭᖏᓐᓂᒃ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ) ᑑᒑᓖᑦ ᑲᑎᕐᒪᑉᓗᑎᒃ ᐊᒥᓲᓂᖏᓐᓄᑦ ᑕᑯᒃᓴᐅᓚᐅᖅᑐᑦ ᓈᓴᐅᑎᒃᑯᑦ ᐅᔾᔨᕐᓇᖅᑐᑦ (*P*>0.2 ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᓗᒃᑖᓄᑦ). **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓖᑦ ᑲᑎᖃᑦᑕᙱᑦᑐᑦ ᐊᒥᓲᓂᖅᓴᐅᔪᓄᑦ ᑲᑎᕐᒪᔪᓄᑦ ᐅᕝᕙᓘᓐᓃᑦ ᐊᒥᓲᙱᓐᓂᖅᓴᓄᑦ ᐱᔾᔪᑎᒋᐸᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᕐᓄᑦ ᖃᓐᓂᓐᖏᑦ.**

- ᑲᑎᒪᔪᑦ:

  - ᑑᒑᓕᓗᒃᑖᑦ ᐆᒪᓂᖏᓐᓄᑦ ᐃᓂᓕᐊᑦ (ᐃᓐᓇᐃᑦ ᐊᕐᓇᓪᓗᐃᑦ, ᐃᓐᓇᐃᑦ ᐊᖑᓯᓪᓗᐃᑦ, ᐃᓐᓇᕈᖅᐸᓪᓕᐊᔪᑦ, ᑑᒑᓕᒃᑖᓯᖑᔪᑦ) ᑎᑎᕋᐅᓯᐅᓚᐅᖅᑐᑦ BSA-ᒥᑦ ᑕᓪᓕᒪᓂᑦ ᐆᒃᑐᕋᐃᓂᕐᒧᑦ ᐅᑭᐅᓂᑦ. ᖃᐅᑕᒫᒃᑯᑦ ᑑᒑᙳᓯᖅᑐᑦ/ᐃᓐᓇᕈᙱᑦᑐᑦ ᓯᓕ ᑎᑎᕋᐅᓯᐅᔪᑦ BSA-ᒥᑦ (ᑲᑎᓗᒃᑖᖅᓱᒋᑦ ᖃᑉᓯᐅᓂᖏᑦ ᑑᒑᓖᑦ ᖃᐅᔨᔭᐅᔪᑦ ᐅᐸᓗᑕᒫᑦ) ᖁᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᖅ 2019-ᒥᑦ (ᐊᕐᕌᒍᑕᒫᖅ 11.2%) ᐅᑭᐅᓂᑦ ᐊᓂᒍᖅᑐᓗᒃᑖᓂᑦ (2014=10.7%, 2016=9.7%, 2017=7.7%), ᐊᑐᙱᓐᓂᖅᑐᖅ 2015 (14%). ᑕᒪᓐᓇ ᐅᖃᖅᑐᖅ ᑑᒑᓕᒃᑖᓯᖑᔪᑦ ᐊᔪᙱᓐᓂᖏᓐᓄᑦ ᐃᓄᕕᓕᖕᒥᑦ 2019-ᒥᑦ ᐊᔾᔨᒋᔭᖓ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᐊᖅᓵᖅᑎᓪᓗᒋᑦ, ᐅᑭᐅᒥᑦ ᐅᑭᐅᒧᑦ ᐊᖏᒡᓕᕚᓪᓕᐊᓂᖃᕋᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓃᑦ BSA-ᒥᑦ.

  - ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᕐᓂᖏᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᓚᐅᖅᑐᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᒥᒃ ᑲᑎᒪᔪᓄᑦ ᑑᒑᓕᒃᑖᓯᖑᔪᑦ ᑕᐃᒪᐅᓂᖏᓐᓄᑦ (ᓲᕐᓗ, ᐱᓕᕆᖃᑎᒋᖕᓂᖏᑦ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᑦ 'ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᒃᑎᒋᓂᖏᓐᓂᑦ', 'ᐅᒥᐊᕐᔪᐊᑦ ᓇᒧᙵᐅᓂᖏᓐᓂᑦ' ᐊᒻᒪᓗ 'ᐅᒥᐊᕐᔪᐊᑦ ᓇᓃᓐᓂᖏᓐᓂᒃ BSA-ᒧᑦ'). ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑲᑎᕐᒪᔪᑦ ᑑᒑᓕᒃᑖᓯᖃᖅᐳᑎᒃ/ᐃᓐᓇᕈᖅᐸᓪᓕᐊᔪᓂᑦ ᐊᔾᔨᕐᓕᒋᓕᐅᖅᑕᖓ ᓯᑕᒪᐅᔪᓂᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᓄᑦ ᐊᑐᖅᑕᐅᔪᓂᒃ (ᓲᕐᓗ, ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᑦ ᑕᐃᑯᖓ/ᑕᐃᑲᙵᑦ BSA-ᒥᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᑦ ᓂᒋᕐᒧᙵᐅᐸᓗᑎᒃ/ᐅᐊᖕᓇᒧᙵᐅᐸᓗᑎᒃ), ᑭᓯᐊᓂ ᐊᖏᒡᓕᒋᐊᖅᑐᑦ ᖃᓄᑕᖏᓐᓄᐊᕐᓂᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ.

  - **ᐊᑕᐅᑦᑎᒃᑯᑦ, ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓖᑦ ᑲᑎᒪᓂᖏᓐᓄᑦ ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᕐᓂᖃᙱᑦᑐᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᓂᑦ ᐅᑭᐅᓂᑦ ᐊᖏᒡᓕᒋᐊᕋᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᕐᓂᖏᑦ ᑖᕝᑯᓇᓂ ᐅᐸᓗᕐᓂᑦ, ᑭᓯᐊᓂ ᐃᓚᖏᑦ ᑲᑎᒪᔪᑦ ᑑᒑᓕᒃᑖᓯᖑᔪᓄᑦ/ᐃᓐᓇᕈᖅᐸᓪᓕᐊᔪᓄᑦ ᖁᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᖅ ᖃᓂᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ (ᖃᐅᔨᒪᔭᐅᖏᒃᑲᓗᐊᖅᐳᓂ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖅ ᐊᖏᖕᒪᖔᑦ).**

- ᑲᑎᒪᔪᑦ ᓯᐊᒻᒪᖕᓂᖏᑦ: ᑑᒑᓖᑦ ᑲᑎᒪᔪᑦ ᖃᐅᔨᔭᐅᓚᔪᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᐱᓕᕆᖃᑎᖃᓗᖕᓂᖅᓴᐅᓂᒃᑯᑦ ᐱᓕᕆᖃᑎᖃᓗᐊᖏᓐᓂᖅᓴᐅᓂᕐᒥᐅᖓᓂᑦ ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅᑕᙱᑎᓪᓗᒍ. ᑲᑎᒪᔪᑦ ᓯᐊᒻᒪᒃᑐᑦ ᐊᓯᐊᙳᓗᐊᖏᑦᑐᖅ ᐅᒥᐊᕐᔪᐊᖃᖅᑎᓪᓗᒍ. ᑭᓯᐊᓂ ᐱᓕᕆᖃᑎᖃᓗᐊᖏᓐᓂᖅᓴᐅᓂᒃᑯᑦ ᐊᑎᕐᓃᑦ ᐱᑕᖃᕈᙱᓐᓂᖅᓴᐅᓚᐅᖅᑐᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᒃᓯᕙᓪᓕᐊᑎᓪᓗᒋᑦ BSA-ᒥᑦ (32%-ᖑᔪᓄᑦ ᐅᐊᖕᓇᒨᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᒻᒪᓗ 30%-ᖑᔪᑦ ᓂᒋᕐᒨᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ) ᐅᒥᐊᕐᔪᐊᑦ BSA-ᒨᙵᐅᔪᓂᐅᖕᒪᓂᑦ (38% ᐅᐊᖕᓇᒨᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᒻᒪᓗ 32% ᓂᒋᕐᒨᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ). **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓖᑦ ᑲᑎᓯᒪᔪᑦ ᓯᐊᒻᒪᖕᓂᖏᑦ ᐊᓯᐊᙳᕐᓂᖃᓗᐊᖏᑦᑐᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᖃᓂᑎᓪᓗᒋᑦ.**

- ᑲᑎᒪᔪᑦ ᐋᖅᑭᖕᓂᖕᒋᑦ: ᑑᒫᓖᑦ ᑲᑎᓯᒪᔪᑦ ᖃᐅᔨᓴᐅᒐᔪᓚᐅᖅᑐᑦ ᓴᓂᓖᕆᒃᓱᑎᒃ ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᖃᓄᐃᖓᓕᖅᑎᑦᑎᔾᔪᓇᖅᑐᖅ ᑭᓯᐊᓂᓗ ᓇᓗᓇᖅᓱᓂ ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᖕᓂᖕᒋᓐᓄᑦ ᑑᒫᓖᑦ ᑲᑎᓯᒪᔪᑦ ᐋᖅᑭᐅᒪᓂᖕᒋᓐᓄᑦ ᓇᓗᓇᓚᐅᖅᑭᑦᑐᖅ ᒪᓕᒃᑕᐅᖕᒪᑦ ᐅᒥᐊᕐᔪᐊᖅ ᓇᒨᖓᐅᓂᖕᖓᓄᑦ, ᐊᔾᔨᖃᕈᖕᒍᑉᓗᓂ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᖅ ᓂᒋᕐᒨᖓᐅᔪᖅ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐅᖓᓯᒃᓯᕙᓕᐊᑉᓗᑎᒃ BSA-ᒥᑦ. ᑭᓯᐊᓂ, ᓇᓕᑐᐃᓐᓇᖅᑭᑦ ᐅᒥᐊᕐᔪᐊᕐᔫᖓᔪᑦ ᓈᓴᐅᓯᕆᓂᒃᑯᑦ ᐅᔾᔨᕐᓇᙱᑦᑐᑦ. **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒫᓖᑦ ᑲᑎᓯᒪᔪᑦ ᐋᖅᑭᖕᓂᖕᒋᑦ ᐊᓯᐊᙳᓗᐊᙱᑦᑐᑦ BSA-ᒥᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᖃᓂᑎᓪᓗᒋᑦ; ᑭᓯᐊᓂ, ᖃᐅᔨᓂᕐᒧᑦ ᓴᙱᓂᐅᔪᖅ ᐅᐸᓗᐊᔾᔪᑎᒧᑦ ᐊᔾᔨᒌᙱᓐᓂᕐᒧᑦ ᐊᑦᑎᒃᑑᔪᖅ.**

- ᑲᑎᒪᔪᑦ ᓇᒨᖓᐅᓂᖕᒋᑦ: ᐅᒥᐊᕐᔪᐊᑦ ᓇᒨᖓᐅᓂᖕᒋᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᖅ ᐊᖕᒋᔪᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖃᕐᓂᖕᒪᓄᑦ ᐃᖕᒋᕐᕋᓂᖕᒋᓐᓄᑦ ᑲᑎᒪᔪᑦ ᑑᒫᓖᑦ BSA-ᒥᑦ (ᓲᕐᓗ, ᐱᓕᕆᖃᑎᒌᖕᓂᖕᒋᓐᓂᒃ ᖃᐅᔨᓴᐅᓚᐅᖅᑐᑦ 'ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᖕᓂᖕᒪᓄᑦ', 'ᐅᒥᐊᕐᔪᐊᖅ ᓇᒨᖓᐅᓂᖕᒪᓄᑦ' ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅ ᓇᓃᓐᓂᖕᒪᓄᑦ' BSA-ᒧᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᖅ ᓇᒨᖓᐅᓂᖕᒪᓄᑦ ᐃᖕᒋᕐᕋᑎᓪᓗᒍ ᑕᑯᒃᓴᐅᓚᐅᖅᑐᖅ ᐊᔾᔨᒌᙱᓐᓂᖃᕐᓂᖕᒪᓄᑦ). ᑲᑎᒪᔪᑦ ᑑᒫᓖᑦ ᖃᐅᔨᓴᐅᖃᑦᑕᓚᐅᖅᑐᑦ ᓂᒋᕐᒨᖓᐅᔪᑦ BSA-ᖁᑦ. ᓂᒋᕐᒨᖓᐅᔪᑦ ᑕᐃᒪᐅᒐᔪᙱᓐᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᒃᓯᕙᓕᐊᑎᓪᓗᒋ BSA-ᒥᑦ, ᐊᒻᒪᓗ ᑕᐃᒪᐅᒐᔫᖕᒍᑉᓗᑎᒃ ᐅᐊᖕᓇᒨᖓᐅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᒃᓯᕙᓕᐊᑎᓪᓗᒋᑦ BSA-ᒥᑦ. **ᖃᐅᔨᓴᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒫᓖᑦ ᓇᒨᖓᐅᓂᖕᒋᑦ ᐊᑐᖃᑦᑕᖅᑐᒃᓴᐅᔪᑦ ᐃᓛᓐᓂᒃᑯᑦ ᖃᒡᓕᑦᑕᐃᓕᓂᕐᒧᑦ ᐅᒥᐊᕐᔪᓂᒃ ᐃᖕᒋᕐᕙᔪᓄᑦ ᕿᙳᐊᒍᑦ (ᓲᕐᓗ, ᑲᑎᒪᔪᑦ ᑑᒫᓖᑦ "ᒪᓕᒃᑕᐃᓕᖃᑦᑕᖅᑐᑦ" ᐅᒥᐊᕐᔪᐊᓂᑦ) ᑭᓯᐊᓂ ᓇᒧᑦ ᐃᖕᒋᕐᕙᓂᖕᒋᑦ ᑑᒫᓖᑦ ᑲᑎᒪᔪᑦ ᐊᒃᑐᖅᑕᐅᖕᒋᓐᓂᖅᓴᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑎᑭᓴᖅᑐᖅᑎᓪᓗᒋᑦ.**

- ᐃᖕᒋᕐᕙᑎᓪᓗᒋᑦ ᓇᑭᖕᓴᕐᓂᖅ: ᐊᒥᓲᓂᖕᓴᐃᑦ ᖃᐅᔨᓴᐅᔪᑦ ᑑᒫᓖᑦ ᑲᑎᒪᔪᓂᑦ ᕿᑎᐊᓃᑦᑐᒥᑦ ᐃᖕᒋᕐᕙᒃᑕᓚᐅᖅᑐ, ᐅᒥᐊᕐᔪᐊᓄᑦ ᖃᓂᒃᑲᓗᐊᖅᑎᓪᓗᒋᑦ. ᓈᓴᐅᑎᑕᒃᑲᓗᐊᖕᒋᓐᓂᐅᔪᖅ ᐅᔾᔨᕐᓇᖅᑐᓂᒃ ᓱᓇᑐᐃᓐᓇᕐᓂᒃ ᐅᒥᐊᕐᔪᐊᓅᖕᒪᔪᓄᑦ ᐅᖃᖅᑐᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖕᒋᕐᕙᔭᒃᑐᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖃᓚᐅᖅᑐᑦ ᑑᒫᓖᑦ ᑲᑎᒪᔪᑦ ᒥᒃᓵᓂᖕᒋᓐᓄᑦ ᓇᑭᖕᓴᕐᓂᖕᒋᑦ. ᓈᓴᐅᑏᑦ/ᑎᑎᖅᑲᐃᑦ ᓇᑭᖕᓴᖅᑐᑦ-ᐃᖕᒋᕐᕙᔪᑦ ᑲᑎᒪᔪᓄᑦ ᓈᒻᒪᓚᐅᖅᑐᑦ ᐆᒃᑐᕋᐃᓂᐊᕐᓗᓂ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᖅ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᑎᓪᓗᒋᑦ ᐊᖕᒋᒡᓕᒋᐊᕐᓂᖕᒪ ᐃᖕᒋᕐᕙᓂᕐᒧᑦ ᓇᑭᖕᓴᕐᓂᖅ BSA-ᒥᑦ. **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒫᓖᑦ ᒥᒃᓵᕆᐊᙱᑦᑐᑦ ᐃᖕᒋᕐᕙᑎᓪᓗᒋᑦ ᓇᑭᖕᓴᕐᓂᖕᒋᑦ ᐅᕝᕙᓘᓐᓃᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᙱᑦᑐᖅ 'ᓄᖅᑲᖅᑐᒥᒃ' ᐱᔪᓂᒃ ᐅᒥᐊᕐᔪᐊᓄᑦ ᖃᓂᑎᓪᓗᒋᑦ.**

- ᐅᖓᓯᖕᓂᖓ ᐃᓗᕝᕕᓕᐅᑉ ᓱᓪᓴᖓᓂᑦ: ᑑᒫᓖᑦ ᑲᑎᒪᔪᑦ ᖃᐅᔨᓴᐅᒐᔪᓚᐅᖅᑐᑦ 300 ᒦᑕᓂᒃ ᐅᖓᓯᒃᑎᕆᐸᓗᑎᒃ ᐃᓗᕝᕕᓕᐅᑉ ᓱᓪᓴᖕᒋᓐᓂᑦ ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᐃᒪᕐᒥᑦ ᑲᑎᒪᔪᑦ (>300 ᒦᑕᓂᒃ) ᖃᐅᔨᓴᐅᒐᔪᙱᓐᓂᖅᓴᐅᓚᐅᖅᑐᑦ Beaufort ᓈᓴᐅᑎᖕᒋᓐᓄᑦ, ᐅᖃᖅᑐᖅ ᒥᒃᓵᓃᓕᕐᓂᖕᒋᑦ ᖃᐅᔨᔪᖕᓇᕐᓂᖕᒋᑦ ᑕᕆᐅᖃᙱᓐᓂᖅᓴᐅᔪᒥᑦ. ᐊᒻᒪᓗ, ᐅᒥᐊᕐᔪᐊᑦ ᐃᖕᒋᕐᕙᔭᒃᑐᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᑦ ᒥᒃᓵᓃᓕᕐᓂᖕᒋᑦ 'ᐅᖓᓯᖕᓂᖕᒋᑦ ᓱᓪᓴᖕᖓᑦ' (ᓲᕐᓗ, ᐱᓕᕆᖃᑎᒌᖕᓂᖃᖅ 'ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᖕᓂᖕᒪᓄᑦ', 'ᐅᒥᐊᕐᔪᐊᖅ ᓇᒨᖓᐅᓂᖕᒪᓄᑦ' ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅ ᓇᓃᓐᓂᖕᒪᓄᑦ'). ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᖅ ᐱᔾᔪᑕᐅᓗᐊᖅᑑᔭᖅᑐᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖕᒋᕐᕙᔭᖕᓂᖕᒋᑦ BSA-ᒨᖓᐅᔪᓄᑦ. **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒫᓖᑦ ᓱᓪᓴᒨᖓᐅᖃᑦᑕᕐᒪᑕ ᖃᓂᑦᑕᕿᖓᑕ ᐅᒥᐊᕐᔪᐊᓄᑦ BSA-ᒨᖓᐅᑉᓗᑎᒃ.**

ᑕᒪᐃᓐᓄᑦ, ᖃᓄᐃᖓᓂᐅᔪᑦ ᑖᓕᓕᒪᓄᑦ-ᐃᒪᕐᒦᖕᒐᔪᓂᑦ ᖃᐅᔨᓴᐃᓂᖅ ᐃᑲᔪᖅᑐᖅ ᐊᒃᑐᖅᓯᓂᕐᓄᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᒃ ᑭᖑᓕᖅᐹᖅ ᐊᕙᑎᒥᒃ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᑎᑎᖅᑲᒥᑦ (FEIS) ᐱᒋᐊᓅᕐᓂᕐᒥᑦ ᑮᓇᐅᔭᓕᐅᕐᓂᕐᒧᑦ (ERP), ᐅᒥᐊᕐᔪᐊᖅ ᓂᐱᖓᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓃᑦ ᑑᒫᓖᖕᓄᑦ ᑭᒡᓕᖃᖅᑐᖅ ᖃᓂᑦᑐᒥᑦ ᖃᒡᓕᑦᑕᐃᓕᓂᕐᒧᑦ, ᐊᔾᔨᒌᙳᖓ ᐊᑦᑎᒃᑑᔭᒥᑦ ᕿᑎᐊᓅᖓᔪᒥᑦ ᖃᓄᑎᒋᐅᓂᖓᑦ ᐅᐸᓗᐊᓂᕐᒧᑦ (Southall et al. 2007; Finneran et al. 2017). ᖃᐅᔨᓚᐅᖅᑐᑦ ᐊᖕᒋᔪᒥᒃ ᖃᒡᓕᑦᑕᐃᓕᓂᖃᕐᓂᖕᒋᓐᓄᑦ, ᐊᓯᐊᓄᐊᕐᓂᖕᒋᓐᓄᑦ, ᕿᒪᐃᓂᖕᒋᓐᓄᓛᓅᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᖃᑦᑕᖅᑕᖕᒋᓂᑦ (ᖃᓄᑎᒋᐅᓂᖓᑦ ᐅᐸᓗᐊᓂᕐᓄᑦ), ᐊᒃᑐᖅᓯᓂᖃᑐᐃᓐᓇᓇᐊᖃᖅᑐᖅ ᐊᒥᓲᓂᖕᒋᓐᓂᒃ (ᐊᔾᔨᒋᔭᖓ ᑐᑭᐅᔪᑦ ᐅᔾᔨᕐᓇᙱᑦᑐᖅ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᑦ ᑭᖑᓖᖅᐹᖅ ᐊᕙᑎᒥᒃ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᑎᑎᖅᑲᒥᑦ).

Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of Baffinland Iron Mines Corporation (Baffinland). The Executive Summary was translated into Inuktitut by wintranslation and provided by Baffinland to Golder. In the event of discrepancies in information or interpretation, the English version shall prevail. This report represents Golder's professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, station conditions, design objective, development and purpose described to Golder by Baffinland, and are not applicable to any other project or station location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. Baffinland may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.

ACRONYMS / ABBREVIATIONS

AIS	Automatic Identification System
AMARs	Autonomous Multichannel Acoustic Recorders
Baffinland	Baffinland Iron Mines Corporation
BSA	Behavioural Study Area
DFO	Fisheries and Oceans Canada
ERP	Early Revenue Phase
Golder	Golder Associates Ltd.
GPS	Global Positioning System
h	Hour
Hz	Hertz
IQ	Inuit Qaujimajatuqangit
JASCO	JASCO Applied Sciences
kHz	Kilohertz
km	Kilometres
LOESS	locally estimated scatterplot smoothing
m	Metres
m/s	metres per second
MMOs	Marine Mammal Observers
MMP	Marine Monitoring Program
Mtpa	million tonnes per annum
PAM	passive acoustic monitoring
PC	Project Certificate
RAD	relative abundance and distribution
RSA	Regional Study Area
SARA	Species at Risk Act
SEL	sound exposure level
SFOC	Special Flight Operations Certificate
SPL_{rms}	sound pressure level (root mean square)
SSA	Stratified Study Area
Steenbsy Port	port at Steensby Inlet
the Program	Bruce Head Shore-based Monitoring Program
the Project	Mary River Project
UAV	Unmanned Aerial Vehicle
VAC	Visual Acoustic Correlation

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This report presents the integrated results of a five-year shore-based monitoring study of narwhal (*Monodon monoceros*) conducted near Bruce Head, North Baffin Island, Nunavut. During the open water seasons of 2014-2017 and in 2019, visual survey data were collected from a cliff-based observation platform overlooking the Mary River Project's Northern Shipping Route to investigate potential narwhal response to shipping activities, with information collected on relative abundance and distribution (RAD), group composition, and behaviour of narwhal. Additional data were collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

1.1 Project Background

The Mary River Project (hereafter, "the Project") is an operating open pit iron ore mine owned by Baffinland Iron Mines Corporation (Baffinland) and located in the Qikiqtani Region of North Baffin Island, Nunavut (Figure 1-1). The operating mine site is connected to Milne Port, located at the head of Milne Inlet, via the 100-km long Milne Inlet Tote Road. An approved but yet-undeveloped component of the Project includes a South Railway connecting the Mine Site to an undeveloped port at Steensby Inlet (Steenbsy Port).

To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is authorized to transport 4.2 Mtpa of ore by truck to Milne Port for shipping through the Northern Shipping Route using chartered ore carrier vessels. A production increase to ship 6.0 Mtpa from Milne Port was approved for 2018 - 2021 and shipping is expected to continue for the life of the Project (20+ years). During the first year of ERP Operations in 2015, Baffinland shipped ~900,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached ~4.2 million tonnes involving 56 return ore carrier voyages. Following approval to increase production to 6.0 Mtpa, a total of 5.44 Mtpa of ore was shipped via 71 return voyages in 2018 and 5.86 Mtpa of ore was shipped via 81 return voyages in 2019.

LEGEND

- PROJECT SITE
- COMMUNITY
- FUTURE SOUTH RAILWAY
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA
- SHIPPING ROUTE
- MARINE MAMMAL REGIONAL STUDY AREA
- SIRMILIK NATIONAL PARK
- WATER

0 125 250

1:5,000,000 KILOMETRES

REFERENCE(S)

BASE MAP: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
PROJECT LOCATION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	1-1

PATH: I:\2016\1663724\Mapping\MXD\23000_2019BruceHeadProgram\1663724_23000_04_Fig1_1_Project_Location_Rev0.mxd PRINTED ON: 2020-08-28 AT: 10:06:48 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A 25mm 0

1.2 Program Objective

The Bruce Head Shore-based Monitoring Program represents one of several environmental monitoring programs that collectively comprise Baffinland's Marine Monitoring Program (MMP) for marine mammals. The Program was designed to specifically address Project Certificate conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes to animal distribution, relative abundance, and migratory movements in the Project's Regional Study Area (RSA; Figure 1-1). Specifically, the Program contributes to the following Project Certificate conditions:

- Condition No. 99c and 101g – "Shore-based observations of pre-Project narwhal and bowhead whale behaviour in Milne Inlet that continues at an appropriate frequency throughout the Early Revenue Phase and for not less than three consecutive years"
- Condition No. 109 (for Milne Inlet specifically) – "The Proponent shall conduct a monitoring program to confirm the predictions in the FEIS with respect to disturbance effects from ships noise on the distribution and occurrence of marine mammals. The survey shall be designed to address effects during the shipping seasons, and include locations in Hudson Strait and Foxe Basin, Milne Inlet, Eclipse Sound, and Pond Inlet. The survey shall continue over a sufficiently lengthy period to determine the extent to which habituation occurs for narwhal, beluga, bowhead and walrus".
- Condition No. 111 – "The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring.

Through the Bruce Head Shore-based Monitoring Program, narwhal response to shipping activities is investigated along the Northern Shipping Route in Milne Inlet, with data collected on relative abundance and distribution (RAD), and group composition and behaviour. Additional data are also collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

Unless stated otherwise, any reference to vessel traffic refers to medium (50 – 100 m in length) and large (>100 m in length) vessels.

1.3 Study Area

The Bruce Head Shore-based Monitoring Program is based at Bruce Head, a high rocky peninsula on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route. The observation platform (renovated in 2019; see Section 3.3) is located on a cliff at Bruce Head, approximately 215 m above sea level (N 72° 4' 17.76", W 80° 32'35.52") and approximately 40 km from Milne Port. From the observation platform, Marine Mammal Observers (MMOs) are provided with a mostly-unobstructed view of Milne Inlet from the southern tip of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south, with the mouth of Koluktoo Bay visible to the south of the Peninsula, and Poirier Island visible to the east (Photograph 3.1).

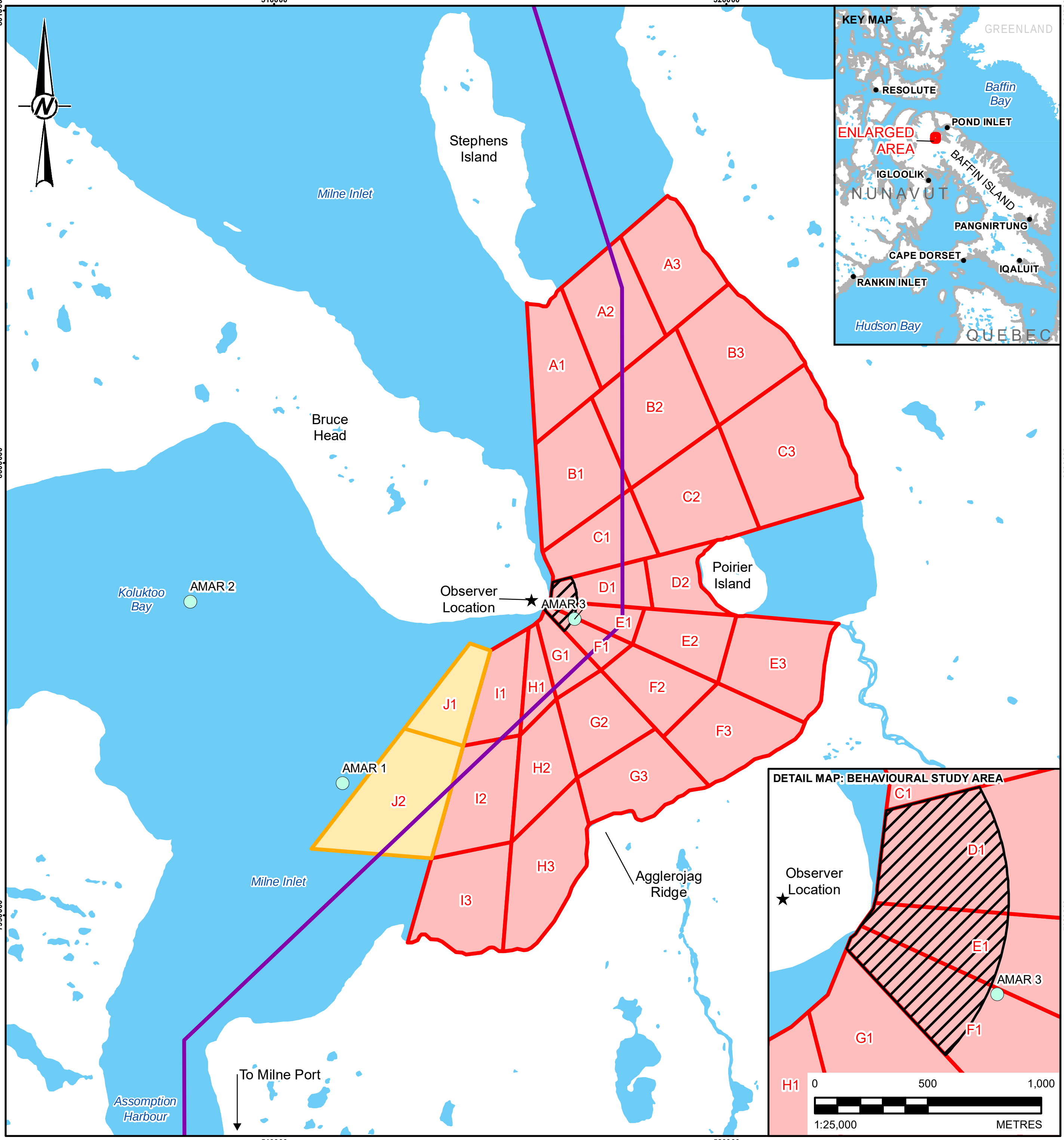
Consistent with previous years, two study areas were used for the 2019 shore-based study depending on the applicable data collection protocol. This included a broader Stratified Study Area (SSA) and a smaller Behavioural Study Area (BSA) nested within the SSA (Figure 1-2).

1.3.1 Stratified Study Area (SSA)

The SSA covers a total area of 90.5 km^2 and was designed for the collection of narwhal relative abundance and distribution data (RAD). The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum) and further separated into substrata 1 through 3 (1 being closest to the Bruce Head shore/observation platform and 3 being the furthest away). With the addition of strata J in 2020 (see Section 3.1), there are a total of 28 substrata within the SSA as stratum D and J are comprised of only 2 substrata, 1 and 2. These substrata boundaries have been visually defined in the field using definitive land marks on the far shore of Milne inlet and nearby islands.

1.3.2 Behavioural Study Area (BSA)

The BSA covers portions of strata D, E, and F that extend 600 m from the shoreline below the Bruce Head observation platform. The BSA spatial boundary was designed for the collection of narwhal group composition and behaviour data. The shoreline adjacent to the BSA is a common narwhal hunting camp for local Inuit.



LEGEND

- AMAR LOCATION
- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA (BSA)
- WATERBODY

STRATIFIED STUDY AREA (SSA) SUBSTRATA

- PREVIOUS SUBSTRATA
- NEW SUBSTRATA

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
STRATIFIED STUDY AREA (SSA) WITH BEHAVIORAL STUDY AREA (BSA) NESTED WITHIN

CONSULTANT

GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	1-2

2.0 SPECIES BACKGROUND

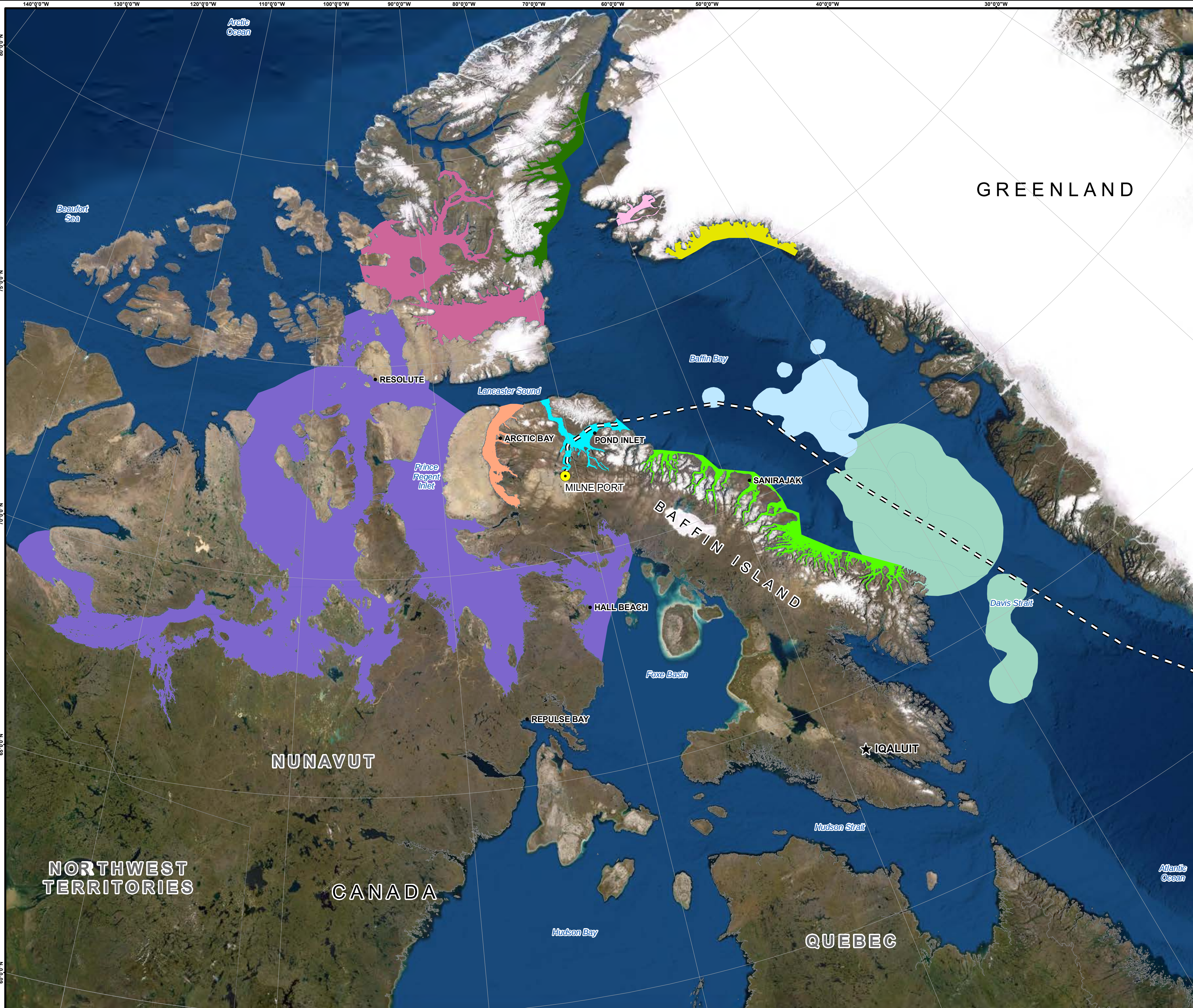
2.1 Population Status and Abundance

Narwhal are endemic to the Arctic, occurring primarily in Baffin Bay, the eastern Canadian Arctic, and the Greenland Sea (Reeves et al. 2012). Seldom present south of 61º N latitude (COSEWIC 2004), two populations are recognized in Canadian waters; the Baffin Bay (BB) population and the northern Hudson Bay (NHB) population (Watt et al. 2017). Of these, only the Baffin Bay population occurs seasonally along the Northern Shipping Route for the Project (Koski and Davis 1994; Dietz et al. 2001; Richard et al. 2010). A third recognized population of narwhal occurs in East Greenland and is not thought to enter Canadian waters (COSEWIC 2004). The populations are distinguished by their summering distributions, as well as a significant difference in nuclear microsatellite markers indicating limited mixing of the populations (DFO 2011).

For management purposes, DFO has defined seven narwhal stocks (i.e., resource units subject to hunting) in Nunavut: Jones Sound, Smith Sound, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, and Northern Hudson Bay (Doniol-Valcroze et al. 2015) (Figure 2-1). These stocks were selected based on satellite tracking data indicating geographic segregation in summer (year-round segregation from the others in the case of the northern Hudson Bay stock) and also on evidence from genetic and contaminants studies that supported this stock partitioning. Subdividing the management units was recommended as a precautionary approach that would reduce the risk of over-exploitation of a segregated unit with site fidelity in summer (Richard et al. 2010). Both narwhal populations in Canada are not presently considered at risk and are not listed under the federal *Species at Risk Act* (*SARA*).

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 represents the most complete survey conducted to date of six major narwhal summering aggregations in the Canadian Arctic (Doniol-Valcroze et al. 2015). The current abundance estimate for the Baffin Bay population, corrected for diving and observer bias, is 141,909 individuals (Doniol-Valcroze et al. 2015). Although narwhal stocks tend to segregate in the summer months, annual variation in stock estimates between Eclipse Sound and Admiralty Inlet suggests that there is movement between these two summering ground locations (Thomas et al. 2015). The corrected estimate for the Eclipse Sound stock is 10,489 narwhal (CV = 0.24) while the corrected estimate for the Admiralty Inlet stock is 35,043 (CV = 0.42) (Doniol-Valcroze et al. 2015).

Results from aerial surveys conducted by Golder in 2019 indicated an abundance estimate of 38,771 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.12, 95% confidence interval CI = 30,667– 49,016; Golder 2020b), which falls within the 95% CI of DFO's 2013 abundance estimate of the combined stock (45,532 narwhals, CV=0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015). For the Eclipse Sound stock alone, the 2019 abundance estimate was 9,931 narwhal (CV = 0.05, 95% CI = 9,009–10,946; Golder 2020b) which falls within the 95% confidence interval of all previous DFO abundance estimates for the Eclipse Sound stock, including the last survey undertaken in 2016 (12,093 narwhal, CV = 0.23, CI = 7,768–18,660; Marcoux et al. 2019).



LEGEND

- ★ TERRITORY CAPITAL
- • COMMUNITY
- MILNE PORT
- SHIPPING ROUTE (APPROXIMATE)

SUMMER AGGREGATION AREA

- ADMIRALTY INLET
- EAST BAFFIN ISLAND
- ECLIPSE SOUND
- INGLEFIELD BREDNING
- JONES SOUND
- MELVILLE BAY
- SMITH SOUND
- SOMERSET ISLAND

WINTER AGGREGATION AREA

- NORTHERN WINTERING AREA
- SOUTHERN WINTERING AREA

0 200 400

1:10,000,000 KILOMETRES

REFERENCE(S)

NARWHAL POPULATION RANGES DIGITIZED FROM DFO FIGURE 1 'MAP OF HIGH ARCTIC NARWHAL SUMMER AGGREGATIONS' (SOURCE: AMMCO/SC/21-JCNB/SWG/14-05). NARWHAL WINTERING AREAS DIGITIZED FROM RICHARD ET AL. (2014) FIGURE 3 PUBLISHED WINTER HOME RANGES OF TRACKED BAFFIN BAY NARWHAL. SHYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. COUNTRY BASE DATA © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED. SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
PROJECTION: CANADA ALBERS EQUAL AREA CONIC DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
NARWHAL SUMMERING AND WINTERING AREAS – BAFFIN BAY POPULATION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	2-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

2.2 Geographic and Seasonal Distribution

Narwhal show high levels of site fidelity, annually returning to well-defined summering and wintering areas (Laidre et al. 2004; Richard et al. 2010). During summer, narwhal tend to remain in inlet areas that are thought to provide protection from the wind (Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). In winter, narwhal move onto feeding grounds located in deep-water offshore areas and the continental slope where water depths are 1,000 to 1,500 m, and where upwelling increases biological productivity and supports abundant prey species (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001; Richard et al. 2010).

Between April and June, narwhal migrate from their Baffin Bay wintering areas to the Pond Inlet floe edge, northern coast of Bylot Island, Navy Board Inlet floe edge, and eastern Lancaster Sound (JPCS 2017). As ice conditions permit (usually late June and July), narwhal move into summering areas in Barrow Strait, Peel Sound, Prince Regent Inlet, Admiralty Inlet, and Eclipse Sound (Cosens and Dueck 1991; Remnant and Thomas 1992; Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). According to Inuit Qaujimajatuqangit (IQ), narwhal first enter into Eclipse Sound in July through leads in the ice, with large males typically entering ahead of females and calves (JPCS 2017). Throughout the summer months, narwhal remain in western Eclipse Sound and associated inlets during which time calves are born and reared (Koski and Davis 1994; Dietz and Heide-Jørgensen 1995; Dietz et al. 2001; Doniol-Valcroze et al. 2015). The distribution of narwhal in Eclipse Sound, Milne Inlet, Koluktoo Bay, and Tremblay Sound during summer is thought to be influenced by the presence and distribution of ice and by the presence of killer whales (Kingsley et al. 1994).

Narwhal generally begin migrating out of their summering areas in late September (Koski and Davis 1994). Individuals exiting Eclipse Sound and Pond Inlet migrate down the east coast of Baffin Island toward overwintering areas in Baffin Bay and Davis Strait (Dietz et al. 2001; JPCS 2017). Depending on ice conditions, specific migratory routes may change from year to year (JPCS 2017). Individuals summering near Somerset Island typically enter Baffin Bay north of Bylot Island in mid- to late October (Heide-Jørgensen et al. 2003). By mid- to late October, narwhal leave Melville Bay and migrate southward along the west coast of Greenland in water depths of 500 to 1000 m (Dietz and Heide-Jørgensen 1995). Narwhal generally arrive at their wintering grounds in Baffin Bay and Davis Strait during November (Heide-Jørgensen et al. 2003) where they associate closely with heavy pack ice comprised of 90 to 99% ice cover (Koski and Davis 1994). Elders have indicated that while the majority of narwhal overwinter in Baffin Bay, some animals remain along the floe edges at Pond Inlet and Navy Board Inlet. Narwhal tracking data have identified two distinct wintering areas for the Baffin Bay population (Richard et al. 2010, Laidre and Heide-Jørgensen 2005). One wintering area is located in northern Davis Strait / southern Baffin Bay (referred to as the southern wintering area) and is frequented by Canadian narwhal summering stocks from Admiralty Inlet and Eclipse Sound, and the Greenland narwhal stock from Melville Bay. The second wintering area is located in central Baffin Bay (referred to as the northern wintering area) and is used by narwhal from the Somerset Island summering stock (Laidre and Heide-Jørgensen 2005).

2.3 Reproduction

Female narwhal are believed to mature at 8 to 9 years of age and produce their first young at 9 to 10 years of age while males mature at 12 to 20 years of age (Garde et al. 2015). Pond Inlet hunters reported that narwhal mating activity occurs in areas off the north coast of Bylot Island and at the floe edge east of Pond Inlet and at the north end of Navy Board Inlet. Eclipse Sound, Tremblay Sound, Milne Inlet, and Koluktoo Bay have also been reported as mating areas (Remnant and Thomas 1992). Conception typically occurs between late March and late May, although mating has been observed in June at the Admiralty Inlet floe edge and in August in western Admiralty Inlet (Stewart 2001). At least one presumed mating event was observed from the Bruce Head observation platform in southern Milne Inlet during the 2016 open-water season (Smith et al. 2017). Calving has been reported in Pond Inlet, Eclipse Sound, Navy Board Inlet, Milne Inlet, and Koluktoo Bay (Remnant and Thomas 1992; JPCS 2017); which is consistent with IQ information indicating that calving has been observed in all areas of North Baffin Island (Furgal and Laing 2012). The birth of a narwhal calf near Bruce Head was also observed in August 2016, which supports IQ and previous suggestions from other research that Milne Inlet is used for calving in addition to calf-rearing (Smith et al. 2017). On average, females are thought to produce a single calf approximately once every two to three years and have a generation time of approximately 30 years (Garde et al. 2015). However, many Inuit believe that narwhal give birth more frequently, perhaps annually (COSEWIC 2004). Gestation for narwhal is on the order of 14-15 months (COSEWIC 2004) with IQ suggesting 15 months based on fetuses observed (Furgal and Laing 2012). Newborn calves are primarily born between May and August each year and measure 140 to 170 cm in length, approximately 1/3 to 1/2 the body length of an adult female (Charry et al. 2018). Typically, newborn calves travel less than one body length away from their mother and in larger group sizes while in Eclipse Sound (mean group size = 5) compared to smaller group sizes along the east coast of Baffin Island (mean group size = 2; Charry et al. 2018). Calves are generally weaned at 1–2 years of age (COSEWIC 2004).

2.4 Diet

Current understanding on narwhal diet is based on studies focusing on stomach content analysis (Finley and Gibb 1982; Laidre and Heide Jørgensen 2005), satellite-based tagging studies (Watt et al. 2015; 2017) and fatty acid and stable isotope analysis (Watt et al. 2013; Watt and Ferguson 2015). Finley and Gibb (1982) analyzed the diet of 73 narwhal near Pond Inlet from June through September (1978-1979) through stomach content analysis and reported food in 92% of the stomachs analyzed. Feeding was found to be most intensive during spring when narwhal occurred near the floe edge and within open leads (Finley and Gibb 1982). Diet consisted of pelagic and benthic species including Arctic cod (*Boreogadus saida*) (identified in 88% of analyzed stomachs), Greenland halibut (*Reinhardtius hippoglossoides*), squid (*Gonatus fabricii*), redfish (*Sebastes marinus*), and polar cod (*Arctogadus glacialis*), with foraging occurring at depths greater than 500 m (Finley and Gibb 1982; Watt et al. 2017).

Deep diving is energetically costly to marine mammals and requires lipid-rich prey or abundant food sources to support this activity (Bluhm and Gradinger 2008; Davis 2014; Watt et al. 2017). Narwhal are well adapted to deep diving and are known to prey on deep-water fish species (Finley and Gibb 1982; Watt et al. 2015) to meet their dietary requirements. Early studies reported that narwhal spend limited time feeding while present on their summering grounds, compared to winter or spring (Mansfield et al. 1975; Finley and Gibb 1982; Laidre et al. 2004; Laidre and Heide-Jørgensen 2005). However, recent studies that have analyzed the spatial and seasonal patterns in narwhal dive behaviour (using targeted deep dives as a proxy for benthic foraging) suggest that, although the majority of dives recorded in Eclipse Sound during the summer occurred near the surface, deep-water dives were also frequently observed, suggesting the occurrence of important benthic foraging areas (Watt et al. 2015; 2017; Golder 2020a). This finding is supported by stable isotope analysis conducted for the Baffin Bay population, in which Greenland halibut and Northern shrimp (*Pandalus borealis*) were identified as the major constituents (>50%) of their summer diet (Watt et al. 2013).

2.5 Locomotive Behaviour

Like many cetacean species that inhabit patchy and/or dynamic environments (Laidre et al. 2003), narwhal surface and dive behaviour varies depending on where they are distributed throughout their summering grounds (Watt et al. 2017; Golder 2020a). The following sections (Section 2.5.1 and 2.5.1) provide context regarding the current understanding of narwhal locomotive behaviour while summering throughout Milne Inlet and adjacent water bodies. Detailed analyses of narwhal surface and dive movements throughout the RSA are presented in the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a).

2.5.1 Surface Movements

Narwhal are a migratory species, travelling large distances between high Arctic summering grounds and low Arctic wintering grounds annually (Laidre and Heide-Jørgensen 2005). Ice conditions permitting, narwhal typically move into summering grounds in Eclipse Sound and adjacent inlets (e.g., Milne Inlet) during late June/July (Remnant and Thomas 1992; Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). Once at their summering grounds, narwhal are widely distributed throughout the open-water fjord complexes and bays (Laidre et al. 2003; Golder 2020a) and rely on the region for important mating and calving activities (Mansfield et al. 1975; Remnant and Thomas 1992; Marcoux et al. 2009; Smith et al. 2017). Following a summer spent in Milne Inlet and adjacent water bodies, narwhal then begin their migration eastward out of Eclipse Sound during mid- to late September (Koski and Davis 1994), where they make their way from Pond Inlet, down the east coast of Baffin Island (Dietz et al. 2001; Golder 2020a), toward winter feeding areas in Baffin Bay (Koski and Davis 1994; Heide-Jørgensen et al. 2002; Laidre et al. 2004).

Narwhal are highly gregarious and are closely associated with one another by nature (Marcoux et al. 2009). Although knowledge regarding the context and function (if any) of narwhal aggregations is incomplete (Marcoux et al. 2009), they have been observed throughout Milne Inlet and Koluktoo Bay in small groups or clusters[1] averaging 3.5 individuals (range: 1 to 25), and in herds[2] of up to hundreds of clusters (Marcoux et al. 2009; Golder 2019). According to Marcoux et al. (2009), herds observed from the Bruce Head Peninsula were composed of 1 to 642 clusters, with a mean of 22.4 clusters/herd. Observations from the Bruce Head Peninsula also reveal that narwhal generally enter Milne Inlet and Koluktoo Bay in larger clusters than when they exit and show strong site fidelity to Koluktoo Bay specifically (Marcoux et al. 2009; Smith et al. 2017; Golder 2019).

Understanding confounding effects such as the presence of predators in a system is important when assessing movement behaviour of cetaceans in relation to vessel traffic. Killer whales (*Orcinus orca*), for example, are well known to prey on narwhal and may affect narwhal space use patterns (Campbell et al. 1988; Cosens and Dueck 1991). In one report by Laidre et al. (2006), an attack was observed in which multiple narwhal were killed by a pod of killer whales over six hours. In the immediate presence of killer whales, narwhal moved slowly, travelling in very shallow water close to shore, and in tight groups at the surface (Laidre et al. 2006). Once the attack commenced, narwhal dispersed widely (approximately doubling their normal spatial distribution), beached themselves in sandy areas, and shifted their distribution away from the attack site. Normal (pre-exposure) behaviour was said to resume shortly (< 1 hour) after the killer whales departed the area (Laidre et al. 2006). This observation is supported by Breed et al. (2017), who suggested that behavioural changes in narwhal extend beyond discrete

[1] Cluster = a group with no individual more than 10 body lengths apart from any other (Marcoux et al. 2009).

[2] Herd = an aggregation of clusters.

predation/attack events, with space use patterns being highly influenced by the mere presence of killer whales in an area. Of note, simultaneous satellite tracking of narwhal and killer whales revealed that narwhal constrained themselves to a narrow band close to shore (≤500 m) when killer whales were present within approximately 100 km (Breed et al. 2017).

Based on findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a), narwhal were shown to alter their surface behaviour in response to vessel traffic by turning back on their own track at distances up to 4 km of a transiting vessel, corresponding to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed). Tagged narwhal were also shown to change their travel orientation relative to transiting vessels at distances up to 5 km of an approaching vessel and up to 10 km of a departing vessel, corresponding to a total exposure period of 54 min per vessel transit (based on a 9 knot travel speed). For both response variables, animals returned to their pre-response behaviour following the vessel exposure period (i.e., a temporary effect). Given that vessels were within 4 to 10 km of a tagged narwhal for <2% to <7% of the GPS datapoints collected in the RSA respectively, the frequency of occurrence of these effects was considered intermittent. Finally, a gap in narwhal distribution evident in close proximity to transiting vessels (0.5 km of a vessel's port and starboard and 1 km of a vessel's bow and stern) suggested movement away from the vessel by narwhal (i.e., avoidance), however this finding may have also been a function of low resolution data available in close proximity to vessels.

2.5.2 Subsurface Movements (Dive Behaviour)

Narwhal are specially adapted for sustained, deep submergence (Martin et al. 1994, Watt et al. 2017). It is generally accepted that depth and duration of narwhal dives are positively correlated given the longer travel time required to reach deeper depths (Laidre et al. 2002; Golder 2020a). Dive data collected in Tremblay Sound revealed a maximum recorded dive duration of 26.2 minutes for one narwhal tagged during August 1999 (mean = 4.9 min; Laidre et al. 2002). Despite this event being presented as one of the longest dives recorded for narwhal at the time, the maximum depth to which this animal dove was only 256 m (mean = 50.8 m; Laidre et al. 2002), likely a result of the dive being limited by bathymetry. Narwhal tagged in Tremblay Sound during August 2010 and August 2011 made the majority of dives to between 400 and 800 m depths (Watt et al. 2017), indicating that these dives took place in adjacent water bodies that offered deeper bathymetry (i.e., Milne Inlet/Eclipse Sound). Most recently, one narwhal tagged during the 2017 Narwhal Tagging Program was recorded undertaking a dive for 30.1 minutes to a depth of 332.5 m in southern Milne Inlet (Golder 2020a).

During the summer months, narwhal spend a large proportion of time near the surface, milling and socially interacting with one another (Pilleri 1983; Heide-Jørgensen et al. 2001). Narwhal (n = 23) tagged near Baffin Island between 2009 and 2012 were estimated to spend approximately 31.4% of their time within 2 m of the surface during the month of August (Watt et al. 2015). Innes et al. (2002) reported a similar value of 38% of time that narwhal spend within 2 m of the surface based on aerial surveys. The proportion of time that narwhal spend within 5 m of the surface is slightly greater; Heide-Jørgensen et al. (2001) reported narwhal (n = 21) spend approximately 45.6% of time within the top five metres of the water column, while Laidre et al. (2002) reported a range of 30-53% of time that narwhal (n = 4) spend within this upper depth. Although mother-calf pairs have been predicted to spend a greater proportion of time at the surface given the limited diving ability of calves (Watt et al. 2015), no obvious pattern between surface time and body length, sex, and/or presence/absence of calves was observed in a study conducted by Heide-Jørgensen et al. (2001).

Heide-Jørgensen et al. (2001) evaluated dive rate (number of dives per hour) of 25 narwhal tagged in Tremblay Sound between 1997 and 1999 and in Melville Bay, West Greenland between 1993 and 1994. According to this study, mean dive rate of all narwhal outfitted with tags during the month of August was 7.4 dives/hour below 8 metres depth, with narwhal from Tremblay Sound having a significantly lower dive rate overall (7.2 dives/hour) compared to animals tagged in Melville Bay (8.6 dives/hour). No diurnal difference was found in narwhal dive rate from either tagging site (Heide-Jørgensen et al. 2001). Furthermore, increasing number of dives (dive rate) had no effect on narwhal surfacing times (0-5 m). Laidre et al. (2002) reported similar dive rates for two narwhal tagged in Tremblay Sound, ranging from 6.0 dives/hour to 10.9 dives/hour.

In regard to descent and ascent speeds, one study conducted by Laidre et al. (2002) determined that a typical dive profile for two narwhal tagged in Tremblay Sound consisted of a steep descent, followed by a short bottom interval, a gradual ascent, and a relatively slow approach to the surface. The two narwhal in this study exhibited mean descent rates of 0.8 m/s and 1.3 m/s and mean ascent rates of 0.7 m/s and 1.5 m/s, respectively (Laidre et al. 2002). According to an older study that tracked the dive behaviour of three narwhal tagged in Tremblay Sound (Martin et al. 1994), the maximum rates of ascent and descent for each dive ≥20 m depth were positively correlated to the depth and duration of the dive. This finding was supported by the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a) in which mean descent rates were strongly correlated with destination depth.

It is important to note that narwhal dive behaviour is variable based on parameters such as sex, life stage, location, season, and activity state (Heide-Jørgensen et al. 2001). For example, differences in dive rates (number of dives per hour) and dive depth have been found to vary between size and sex of narwhal tagged, with female narwhal generally diving shallower and having lower dive rates than males (Heide-Jørgensen and Dietz 1995). Surprisingly, female narwhal have also been found to spend more time at depth compared to males (Watt et al. 2015; Golder 2020a), despite hypotheses that those with larger body size (i.e., males) would have enhanced ability to dive deeper and for greater periods of time. Whether a female is with or without a calf may also influence dive behaviour, given the aerobic limitations of the young (Watt et al. 2015), though studies conducted by Heide-Jørgensen and Dietz (1995) found no difference in dive behaviour between female narwhal with and without calves. The depths to which narwhal dive are also known to vary with season (Watt et al. 2015; Watt et al. 2017). In general, narwhal make relatively short, shallow dives while on their summering grounds (with depths often limited by the seabed bathymetry), increasing their dive depth and duration in the fall months (Heide-Jørgensen et al. 2002), and making the deepest dives while over-wintering in the pack ice in Baffin Bay (Laidre et al. 2003). Tidal and circadian cycles are not thought to influence narwhal movement patterns (Martin et al. 1994; Born 1986; Dietz and Heide-Jørgensen 1995; Marcoux et al. 2009) and predation by killer whales is not a significant predictor of narwhal dive behaviour but, as discussed in the Section 2.5.1, does influence narwhal spatial distribution at the surface (Watt et al. 2017).

Based on findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a), narwhal were shown to alter their dive behaviour in response to vessel traffic by decreasing their surface time and their total dive duration at distances up to 1 km of a vessel, suggesting that individuals within this exposure zone undertook a greater number of relatively shorter duration dives. For narwhal that were presumed to be engaged in foraging (i.e., performing bottom dives to >75% available bathymetry), individuals were shown to reduce the number of subsequent bottom dives when they were within 5 km of a transiting vessel. No significant effects of vessel traffic on narwhal dive behaviour were observed for dive rate, time at depth (i.e., time within the deepest 20% of dive), descent speed, or bottom dives for narwhal not actively engaged in bottom diving at the initial time of exposure. The distance at which significant changes were observed in dive behaviour (i.e., 1 to 5 km) corresponded with an exposure period ranging from 7 to 36 min per vessel transit (based on a 9 knot travel speed), with animals returning to their pre-response behaviour following the vessel exposure period (i.e., a temporary effect). The frequency of this effect was considered intermittent given that vessels were within 5 km of a tagged narwhal for <1% of the GPS datapoints collected in the RSA during 2017 and 2018.

2.6 Acoustic Behaviour

Like all cetaceans, narwhal depend on the transmission and reception of sound in order to carry out the majority of critical life functions (i.e., communication, reproduction, navigation, detection of prey, and avoidance of predators; Holt et al. 2013). For Arctic cetaceans that are closely associated with sea ice (e.g., narwhal), they are also likely dependent on sound for locating leads and polynyas in the ice for breathing (Richardson et al. 1995; Heide-Jørgensen et al. 2013b; Hauser et al. 2018).

2.6.1 Vocalizations

Narwhal are a highly vocal species that produce a combination of pulsed calls, clicks, and whistles (Ford and Fisher 1978; Marcoux et al. 2011). Pulsed calls are the predominant form of narwhal vocalization and are comprised of pulsed tones and click series (Ford and Fisher 1978). Pulsed tones emitted by narwhal possess pulsed repetition rates that have distinct tonal properties and are generally concentrated between 500 Hz and 5 kHz (Ford and Fisher 1978; Shapiro 2006). Click series are broadband and are concentrated between 12 and 24 kHz, though many click series with low repetition rates are concentrated at lower frequencies between 500 Hz and 5 kHz (Ford and Fisher 1978). High frequency broadband echolocation clicks emitted by narwhal extend up to and beyond 150 kHz (Miller et al. 1995; Rasmussen et al. 2015). Finally, whistles are typically emitted between 300 Hz and 10 kHz, though some whistles have been found to reach frequencies as high as 18 kHz (Ford and Fisher 1978; Marcoux et al. 2011). More recent studies that include recordings at higher sampling rates have allowed for a more complete description of narwhal vocalizations (Rasmussen et al. 2015; Koblitz et al. 2016).

2.6.2 Hearing

Depending on the level and frequency of the sound signal, marine mammal groups with similar hearing capability will experience sound differently than other groups (Southall et al. 2007; Southall et al. 2019). According to updated marine mammal noise exposure criteria by Southall et al. (2019), narwhal, like a selection of other toothed whales previously considered mid-frequency cetaceans, are now considered high-frequency cetaceans whose functional hearing range likely occurs between 150 Hz and 160 kHz (Southall et al. 2007; Southall et al. 2019). Although no behavioural or electrophysiological audiograms are currently available for narwhal specifically (Rasmussen et al. 2015), auditory response curves for this grouping of cetaceans suggest maximum hearing sensitivity in frequencies between 1 kHz and 20 kHz (corresponding to social sound signals) and between 10 kHz and 100 kHz (corresponding to echolocation signals) (Tougaard et al. 2014; Veirs et al. 2016; Southall et al. 2019).

2.6.3 Narwhal and Vessel Noise

Behavioural responses of marine mammals exposed to vessel traffic and associated noise have been documented for several species, however limited information is available for cetaceans inhabiting Arctic waters and for narwhal specifically. Vessel disturbance may elicit several different behavioural responses in cetaceans, including a shift in travel speed or dive rate, freeze or flight (avoidance) response, and short- or long-term displacement from optimal habitat, all of which have the potential to affect subpopulation viability. Of note, narwhal have been shown to react at relatively low received sound levels to distant icebreaking vessels actively breaking ice (Finley et al. 1990; Cosens and Dueck 1993).

In comparing the proposed hearing range of narwhal to the sound output of transiting vessels, the majority of underwater sound generated by vessel traffic is concentrated in the lower frequencies between 20 and 200 Hz (Veirs et al. 2016). Propeller cavitation accounts for peak spectral power between 50-150 Hz while propulsion noise (from engines, gears, and other machinery) generates noise below 50 Hz (Veirs et al. 2016). Broadband noise generated by propeller cavitation has, however, been found to radiate into the higher frequencies up to 100 kHz (Arveson and Vendittis 2000; Veirs et al. 2016), overlapping with the range of maximum hearing sensitivity of narwhal. Therefore, while vessels associated with the Project would generate some broadband noise in the proposed hearing range of narwhal and other high-frequency cetaceans, the majority of sound energy produced is likely concentrated below the peak hearing sensitivity of narwhal (>1 kHz).

Sound level (or 'intensity') must also be considered when assessing the behavioural response of narwhal to vessel-generated noise. Of note, two metrics commonly used to describe and evaluate the effects of non-impulsive sound on marine mammals are sound pressure level (SPL_{rms}; dB re: 1µPa) and sound exposure level (SEL; dB re: $1µPa^2 \cdot s$). Sound pressure level (SPL_{rms}) refers to the average of the squared sound pressure over some duration, while sound exposure level (SEL) is a cumulative measure of sound energy that takes into account the duration of exposure (Southall et al. 2007; NMFS 2018; Southall et al. 2019). It is generally accepted that cetaceans exposed to received sound levels above 120 dB re: 1µPa (SPL_{rms}) will begin to experience behavioural disturbance effects, though the specific behavioural responses exhibited is highly variable depending on the context of species, populations, and/or individuals exposed to the sound source (Southall et al. 2007; Ellison et al. 2012; Williams et al. 2013; NMFS 2018; Southall et al. 2019). For high-frequency cetaceans exposed to non-impulsive received sound levels exceeding 198 dB re: $1µPa^2 \cdot s$ (SEL_{24h}), they may begin to experience auditory injury effects (i.e., permanent hearing loss) (NMFS 2018; Southall et al. 2019).

Acoustic modeling of ore carriers transiting at 9 knots along the Northern Shipping Route was undertaken by JASCO Applied Sciences (JASCO) in 2018 that considered the spectral content for vessel operations up to 25 kHz (Quijano et al. 2017). Modeling results predicted that ore carriers transiting through Milne Inlet would not reach the SEL_{24h} injury threshold[3] at ranges beyond 20 m from the center of the vessel. However, the 120 dB re 1µPa (SPL_{rms}) disturbance threshold[4] was predicted to be exceeded at distances up to 19 km for Post-Panamax carriers (9.82 km < R_{max} < 19.24 km), and up to 29 km for Cape size carriers (12.34 km < R_{max} < 29.29 km), though model estimates were later shown to be overly conservative compared to sound levels measured via passive acoustic recording in 2018 (Frouin-Mouy et al. 2019). These modeling results, together with studies suggesting that narwhal respond to vessel traffic by huddling in groups, ceasing sound production, exhibiting a "freeze response", becoming displaced, or generally altering their behaviour, warrant further investigation into the potential effects of vessel traffic on narwhal behaviour (Cosens and Dueck 1988; Finley et al. 1990; Cosens and Dueck 1993; Heide-Jørgensen et al. 2013a).

[3] Injury thresholds reported have auditory weighting functions applied, meaning that the frequencies in which the animal hears well are emphasized and the frequencies that the animal hears less well or not at all are de-emphasized, based on the animal's audiogram (NMFS 2018; Southall et al. 2019).

[4] The disturbance threshold is broadband, meaning that the total sound pressure level (SPL) is measured over the specified frequency range (i.e. 25 kHz).

Current scientific practice (Southall et al. 2007; Finneran et al. 2017) involves categorizing marine mammal behavioural responses to anthropogenic sound sources based on a severity scale described as low, moderate, or high. Low severity responses are within an animal's range of typical (baseline) behaviours and are unlikely to disrupt an individual to a point where natural behaviour patterns are significantly altered or abandoned. Low severity responses would include:

- Orientation response
- Startle response
- Change in respiration
- Change in heart rate
- Change in group spacing or synchrony

Moderate severity responses would not be considered significant behavioural responses if they lasted for a short duration and the animal immediately returned to their pre-response behaviour. Moderate severity responses would be considered significant behavioural responses if they were sustained for a long duration. What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response and species characteristics such as body size, feeding strategy, and behavioural state at the time of the exposure. In general, a response would be considered 'long-duration' if it lasted up to several hours, or enough time to significantly disrupt an animal's daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that lasted for the full duration of vessel exposure or longer. This assumption was made because examination of behavioural response data suggests that had the vessel exposure continued, the behavioural responses would have continued as well.

Moderate severity responses would include:

- Altering migration path, locomotion (speed, heading), dive profiles
- Stopping/altering nursing, breeding, feeding/foraging, sheltering/resting, vocal behaviour
- Avoiding area near sound source
- Displays of aggression or annoyance (e.g., tail slapping)

High severity responses include those with immediate consequences to growth, survival, or growth, and those affecting animals in vulnerable life stages (i.e., calf, yearling). High severity responses are therefore always considered to be significant.

High severity responses would include:

- Long-term or permanent abandonment of area
- Prolonged separation of females and dependent offspring
- Panic, flight, or stampede
- Stranding

3.0 CHANGES TO 2019 PROGRAM DESIGN

Based on collection and analysis of data obtained during previous Bruce Head Shore-based Monitoring Programs (2014-2017), as well as consultation with the various stakeholder groups (i.e., the Marine Environment Working Group), it was determined that certain modifications to the study design would provide for a more comprehensive picture of potential effects to narwhal resulting from Project-related shipping activities. Of note, changes to the 2019 study design included an extension of the SSA boundary to include the mouth of Koluktoo Bay, and integration of acoustic data collection and Unmanned Aerial Vehicle (UAV) data collection.

3.1 Expansion of Stratified Study Area (SSA) Boundary

The existing Stratified Study Area (SSA) was expanded for the 2019 field season to include additional substrata (J1 and J2) with the aim of evaluating narwhal movements at the mouth of Koluktoo Bay in relation to vessel traffic. Of particular interest was the apparent ‘pulsing’ of narwhal groups in and out of Koluktoo Bay that has been observed anecdotally in past years (Smith et al. 2015, 2016, 2017; Golder 2018, 2019), and whether these movements are related to vessel disturbance or simply to variation in their natural habitat (e.g. tidal cycles, prey availability, etc.).

3.2 Integration of Unmanned Aerial Vehicle (UAV) Survey

During the 2019 field season, Golder subcontracted Arctic UAV to conduct a survey of narwhal in the vicinity of Bruce Head using an Unmanned Aerial Vehicle (UAV), under the SFOC (Special Flight Operations Certificate) permit 930033 obtained from Transport Canada. The primary objectives for collecting data via the UAV were 1) to ground truth sightability of narwhal from the vantage point of the observation platform and 2) to provide "snapshots" of number of animals in the vicinity of the AMARs in order to correlate visual observations of narwhal with acoustic behaviour.

Due to a combination of inclement weather, as well as logistical and technical constraints by the subcontractor, the limited data collected by the UAV were insufficient to inform either of the objectives stated previously. As such, Golder recommends a more robust UAV program to be carried out in 2020, incorporating lessons learned from the 2019 field program.

3.3 Additional Modifications to the Program

In addition to changes to the Program's Study Design, changes to the existing camp accommodation and observation platform at Bruce Head were made during the 2019 field season. Specifically, the camp that was previously located approximately 1 km from where MMOs collected observational data was re-located in 2019 to be adjacent to the observation platform. This relocation was completed in response to health and safety concerns identified by Baffinland regarding hazards associated with the 40-minute hike between the camp and the observation platform undertaken by MMOs in previous years. In addition to this, following the destruction of the wooden observation platform during a severe windstorm in 2017, the observation platform was re-built in 2019 (Photographs 3.1 to 3.3) and will be replaced with a steel container structure during the 2020 field season.

In 2019, the weather station that was used in previous study years was not available for deployment. Therefore, no weather data (air temperature, wind speed, and wind direction) were collected in 2019. These data were not previously used in the integrated quantitative analysis of Bruce Head data, and the change therefore does not affect the analytical approach.

Photograph 3.1: Accommodation at Bruce Head overlooking Milne Inlet and Poirier Island, 2019.

Photograph 3.2: Accommodation at Bruce Head, with observation platform, overlooking Milne Inlet.

Photograph 3.3: Observation platform overlooking Milne Inlet, 2019.

4.0 METHODS

4.1 Study Team and Training

The 2019 field program took place between 4 August 2019 and 3 September 2019 and consisted of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of 5 individuals each, alternating at 4 h observation intervals. Study teams consisted of Golder biologists with previous marine mammal survey experience, a university graduate student, and local Inuit marine mammal observers (Photographs 4.1 and 4.2). A partial changeover of field staff occurred at the mid-point of the study period (14 August 2019), with the university graduate student remaining for the entire duration of the program, and one of the Inuit marine mammal observers remaining for an additional week, for the purpose of maintaining continuity between the two study teams.

Upon arrival to the Bruce Head camp on 4 August 2019, the field team participated in an on-site orientation led by the Camp Manager, Shea Pollard, with support from Golder Biologists, Ainsley Allen and Mitch Firman. Topics covered during the orientation included general camp etiquette expectations, proper use of camp facilities, and health and safety including rifle use storage and expectations while in camp, polar bear awareness, communication procedures, and identification of general hazards in and around camp. All relevant health and safety policies and regulations by Golder and Baffinland were reviewed and discussed. The second study team rotation received on-site orientation upon their respective arrival dates.

During the first day at the Bruce Head observation platform (5 August 2019), the study team participated in a comprehensive training session, led by Ainsley Allen and Mitch Firman. This practical training session included observational survey procedures, data collection techniques, proper use of equipment, data recording and data entry, and post-processing of the survey data. During the training session, all study team members were provided with a Training Manual (Appendix A). Topics covered during the training session included the following study components:

- Spatial boundaries of the Stratified Study Area (SSA) and Behavioural Study Area (BSA)
- Methodology for recording narwhal sightings (i.e., number of individuals, group size, direction of travel)
- Methodology for identifying group formation and group composition
- Methodology for differentiating types of narwhal behaviour
- Methodology for recording weather conditions and sightability conditions[5]
- Methodology for recording vessel presence

---

[5] Sightability was evaluated subjectively by the observer based of overall viewing conditions. It was classified to one of the following five categories:

- Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
- Good (G): conditions such that marine mammals at surface would very likely be detected.
- Moderate (M): conditions such that marine mammals at surface may be detected.
- Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
- Impossible (I): water is completely obscured by fog, ice, or high sea state.

Photograph 4.1: 2019 Field Team – Leg 1.

Photograph 4.2: 2019 Field Team – Leg 2.

4.2 Data Collection

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing behavioural response to a potential perceived threat (i.e. vessel traffic). Narwhal are highly gregarious, are closely associated with one another in nature (Marcoux et al. 2009; Smith et al. 2015; Smith et al. 2016; Smith et al. 2017; Golder 2019), and are known to alter their spatial use patterns in the presence of predators (Campbell et al. 1988; Cosens and Dueck 1991; Laidre et al. 2006; Breed et al. 2017). In drawing from accounts of predator-induced behavioural responses by narwhal, it was determined that the following metrics be examined to assess behavioural response to other potential perceived threats such as vessel traffic: relative abundance and distribution, group size, group composition, group spread, group formation, group direction, travel speed, and distance from shore.

Visual survey data collected during the 2014-2017 and 2019 Bruce Head shore-based monitoring program included information on (1) narwhal relative abundance and distribution (RAD); (2) narwhal group composition and behaviour; and (3) vessel traffic and other anthropogenic activities. During each monitoring shift, the study team was split into two separate groups. The first group, composed of two observers, was exclusively responsible for collecting RAD data in the SSA. The second group, composed of three to four observers, was responsible for collecting data on group composition and behaviour in the BSA, as well as tracking vessels and recording anthropogenic activities in the SSA. Both teams also collected data on environmental conditions during their respective survey efforts. In order to minimize potential observer fatigue, study team members rotated between observer and recorder roles throughout each monitoring shift. Detailed descriptions of data collection and survey methods employed during the 2014–2017 programs are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019).

4.2.1 Relative Abundance and Distribution of Narwhal

Consistent with previous years' data collection techniques (2014-2017), RAD surveys were conducted throughout the SSA in 2019. Observations were made using survey and scan observation (Mann 1999), where the observer surveyed each stratum for a minimum of three minutes to identify narwhal groups, group size (solitary narwhal were considered a group of one), and travel direction. Once all narwhal present within each substratum were counted and their direction of travel recorded, the observer moved on to the next substratum. Where the majority of narwhal were travelling in one direction (e.g., north → south), the observer would begin counting strata from the opposite direction (e.g., south → north) in order to minimize the potential of double counting groups. RAD counts were conducted throughout the SSA at the start of each daily monitoring period and every hour, on the hour. In addition, RAD counts were conducted just before a vessel entered the SSA at either the northern or southern border of the SSA, when the vessel was roughly in the centre of the SSA, and just after a vessel exited the SSA. During vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel.

4.2.2 Group Composition and Behaviour of Narwhal

Group composition and nearshore behavioural data were collected on all narwhal observed within the BSA (<1 km from shore). Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 4-1) before moving onto the next sighting. Observations were made using a combination of Big Eye binoculars (25 x 100), 10 x 42 and 7 x 50 binoculars, and the naked eye. When large herding events took place and RAD team members were not conducting a RAD count, the RAD team assisted in collecting group composition data in the BSA. The data collection protocols were similar across all years of sampling (2014-2017, 2019). A detailed description of group composition and behavioural data collected is provided in the Training Manual (Appendix A).

Table 4-1: Group composition and behavioural data collected in the BSA

Recorded Data	Description
Time of sighting	Time of initial observation within the BSA
Sighting number	A sighting number was used as a unique identifier for each single whale or group of whales
Marine mammal species	All marine species observed were recorded as a separate sighting
Group size[1]	Number of narwhal within one body length of one another
Number of narwhal by tusk classification	■ Number of narwhal with tusks ■ Number of narwhal without tusks ■ Number of narwhal with unknown tusks (i.e., head not visible)
Number of narwhal by age category	Adult, juvenile, yearling, calf, unknown life stage (Table 4-2)
Spread of group	■ Tight: narwhal ≤ 1 body width apart ■ Loose: narwhal >1 body width apart
Group formation	Linear, parallel, cluster, non-directional line, no formation (Table 4-3)
Direction of travel	North, South, East, West
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer: >300 m
Primary and secondary behaviour	See Table 8 (Behavioural Data) in the Training Manual (Appendix A) for lists of primary and secondary behaviours recorded

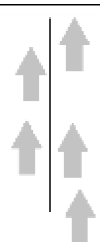
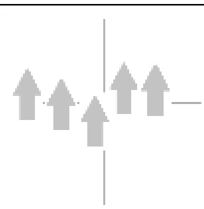
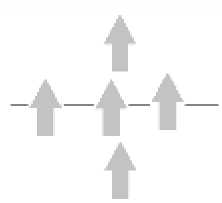
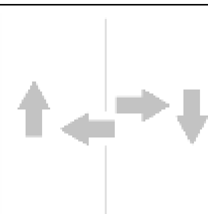
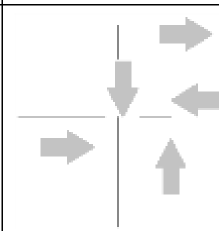
Notes:

[1] This included a group size of n = 1.

Table 4-2: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% the length of adult	2/3 the length of accompanying female	1/3 to 1/2 the length of accompanying female, usually in “baby” or “echelon” position close to mother.
Coloration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey

Table 4-3: Group formation categories

Linear	Parallel	Cluster	Non-directional line	No formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight line	Animals swimming next to each other in a line formation	Animals swimming in cross formation (equally long as wide lines)	Animals in a linear line but facing different directions	Equal spread with no clear pattern
				

4.2.3 Vessel Transits

Vessel transits within the SSA were tracked and recorded using a combination of shore-based and satellite AIS data to provide accurate real-time data on all medium (50 - 100 m in length) and large (>100 m in length) vessel passages through Milne Inlet. AIS transponders are mandatory on all commercial vessels >300 gross tonnage and on all passenger ships. Information provided by the AIS includes vessel name and unique identification number, vessel size and class, position and heading, course, and speed of travel, and destination port. The two datasets were used to complement one another as the AIS shore-based station at Bruce Head provided higher resolution positional data, but only provided line-of sight spatial coverage, while the satellite-based AIS data was lower resolution but provided coverage of the entire Northern Shipping Route.

The study teams also visually recorded vessel traffic in the SSA during each survey period. Vessels were classified by size (small <50 m, medium 50-100 m, and large >100 m in length), type of vessel, and general travel direction. Small vessels were modeled as total count present during each RAD count.

4.2.4 Non-vessel Anthropogenic Activity

The rocky shoreline below the Bruce Head observation platform serves intermittently as a hunting camp for Inuit from local communities. Over the course of the 2014-2017 and 2019 field programs, active shooting events associated with hunting were regularly witnessed by the study team both visually and acoustically from the observation platform. All hunting (i.e., shooting) events were recorded during each daily monitoring period, including the time of occurrence, duration of the event, number of shots fired, and target species. In addition, a pair of Wildlife Acoustic SM4 recorders were set up approximately 50 m from the hunting camp to record hunting events during times that the study team was not actively monitoring (Photograph 4.3). Both recorders recorded continuously using the built in omni-directional microphones, with one recorder sampling at a rate of 24 kHz and the other at 48 kHz.

Photograph 4.3: Two SM4 acoustic recorders mounted back-to-back on a fiberglass pole. The shoreline location of the Inuit hunting camp is visible in the background.

4.2.5 Environmental Conditions

Environmental conditions were recorded at the start of the monitoring period, every hour, and whenever conditions changed. For the entire SSA, cloud cover (percent [%]), precipitation, and ice cover (%) were recorded. Beaufort scale, sun glare, and an overall assessment of sightability were recorded for each substratum within the SSA and also in the BSA. In all years, modeled tidal data for Bruce Head were obtained from WebTide Tidal Prediction Model (v 0.7.1). These tidal data were provided as tide height (m) relative to chart datum. A derivative variable of elevation change (as cm/5 min) was calculated by subtracting each data point from the previous recorded tide height point.

4.2.6 Acoustic Data

Underwater acoustic data in the vicinity of Bruce Head were collected via three Autonomous Multichannel Acoustic Recorders (AMARs) deployed by JASCO Applied Sciences (Figure 1-2). Detailed results from the Passive Acoustic Monitoring (PAM) Program are presented in Frouin-Mouy et al. (2020).

4.2.7 UAV Data

The ability of MMOs stationed at Bruce Head to detect narwhal is potentially biased at increased distances or at low visibility (Golder 2019). To assess potential observer bias, aerial photography of the SSA was desired to compare with concurrent visual observations of the SSA. Arctic UAV was contracted to complete aerial photography of the SSA during the week of August 23 to 29, 2019. Arctic UAV deployed a Wingcopter fixed-wing UAV carrying a Sony α7R II 42.4 megapixel camera for aerial photography. The size of the SSA required that a SFOC from Transport Canada was needed to perform Beyond Visual Line Of Sight (BVLOS) operations (SFOC #930033).

The UAV was flown at an altitude of 295 meters with a 25 mm lens which resulted in photographic resolution of approximately 6 cm per pixel (photo frame of 424 by 283 meters). This resolution was sufficient to detect narwhal calves alongside their mothers. Planned transect spacing and photo intervals resulted in a photo overlap of approximately 10% between adjacent photos. The period of time used to visually assess narwhal numbers in a substratum mimicked that of a RAD count survey (between 1 and 3 minutes per substratum) while the UAV took between 8 and 14 minutes to complete a substratum. UAV battery limitations required that two separate UAV flights were necessary to photograph a single stratum. Photographs were visually assessed to determine number of narwhal and remove narwhal re-sightings due to the photo overlap.

4.3 Data Management

At the end of each daily monitoring period, study team members reviewed field data sheets as a means for quality control and assurance. Any discrepancies/omissions in the data were addressed immediately while the study team maintained a memory of the day’s events. All data sheets were photographed and saved as a digital record on both the laptop and an external hard drive, and original data sheets were filed in a binder at the Bruce Head camp.

Upon completion of the field program, data were entered into a Microsoft Access© database customized for the Bruce Head Program. Data entered into the database were quality checked a second time for missing and/or incorrectly entered fields, as well as discrepancies, and cross referenced with field notes taken during each monitoring period. Observations related to vessel traffic in the SSA were also cross-referenced against AIS data.

4.4 Data Analysis

4.4.1 Data Preparation for Analysis

4.4.1.1 Data Integration between Sampling Years

In 2014 and 2015, sightability categories included Excellent (E), Good (G), Poor (P), and Impossible (X). In 2016 and 2017, an additional category was added: Moderate (M). Due to inconsistencies in how sightability was assessed between survey years (particularly in substrata 3), sightability was instead assessed using a combination of Beaufort scale, level of glare, and substratum (as a measure of distance).

For the 2014 RAD surveys, the time stamp associated with each substratum survey was identical (i.e., only the timing of start of the overall RAD count was recorded, not the timing of each stratum or substratum survey). Since vessel passage and anthropogenic activity are tied to RAD data via time stamps, it was required to provide substratum-specific start times. To calculate these, it was assumed that a full RAD survey required 27 min (three minutes per stratum × nine strata). Each stratum was then allocated three minutes (one minute per substratum), and time stamps were allocated to each substratum.

The 2014 and 2015 satellite-based AIS data did not include information on 'vessel heading'; and in 2014, there was no information on 'vessel speed'. In these cases, missing variables were reconstructed based on consecutive vessel relocations.

For BSA surveys conducted in 2014, 2015, and 2016, sighting data were limited to substrata E1 and F1 (within 1 km from shore). For BSA surveys conducted in 2017, sightings data also included substratum D1 (within 1 km from shore). This change in the extent of the BSA resulted in a shift in the centroid of the BSA from a longitude of -80.52394° to a longitude of -80.52319. The latitude value shifted from 72.06899° to a latitude of 72.07098. The expanded 2017 BSA study area should have no effect on the main variables of interest (group size, composition, spread, formation, direction, speed, and distance from shore), although it could bias the number of narwhal groups observed, due to the larger survey area. To account for this discrepancy and other potential inter-annual effects, the year of sampling was included as a covariate in the BSA models.

4.4.1.2 Automatic Identification System (AIS) Data

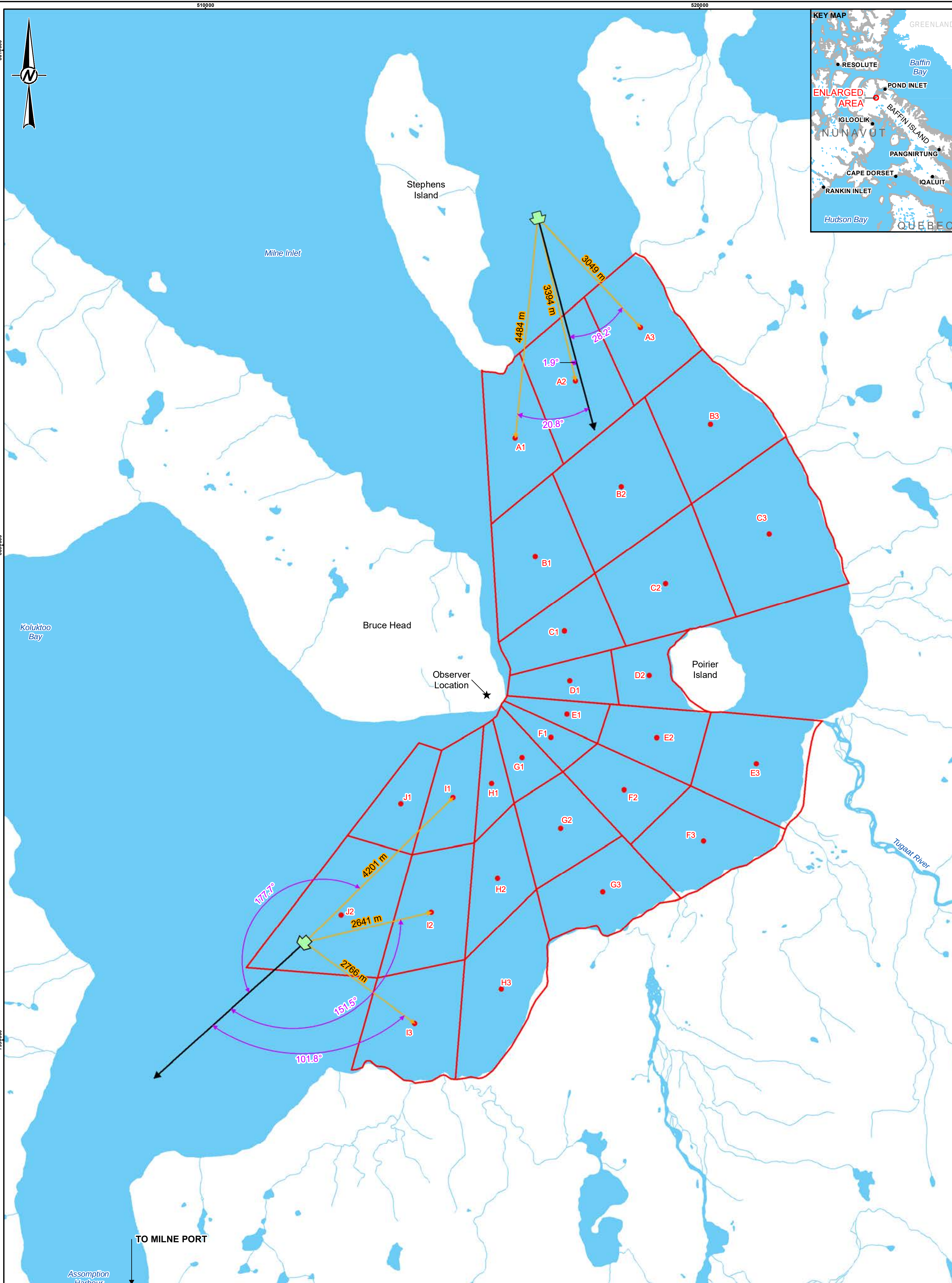
Satellite-based AIS data were merged with the AIS base station data. The full AIS dataset was clipped to only include ship tracking data collected in the Bruce Head study area (between Stephens Island and Milne Port). The full positioning dataset obtained in 2019 from the Bruce Head shore-based AIS station had a mean of 0.2 minutes between positions (range of 0.02-958 minutes, median of 0.2 minutes, SD of 2.9 minutes). The distances between positions ranged from 0 km to 3.1 km (mean of 0.04 km, median of 0.04 km, and SD of 0.02 km). Positioning data from the AIS satellite only (i.e., with removed Bruce Head antenna data) had a mean of 0.6 minutes between positions (range of 0-783 minutes, median of 0.3 minutes, SD of 6.8 minutes). The distances between positions ranged from 0 km to 1.0 km (mean of 0.09 km, median of 0.04 km, and SD of 0.12 km).

AIS data were subsequently filtered to only include data collected during active RAD/BSA survey periods at the platform. In AIS positioning data filtered to the temporal extent of RAD/BSA sampling, only 2.3% of the AIS data were contributed by satellite data. The combined shore-based and satellite dataset had a mean of 0.2 minutes between positions (range of 0-546 minutes, median of 0.2 minutes, SD of 2.8 minutes). The distances between positions ranged from 0 km to 1.0 km (mean of 0.04 km, median of 0.04 km, and SD of 0.03 km).

Each point in the compiled AIS dataset was used to calculate the distance and angle between the ship's position and each centroid of the 28 SSA substrata (Figure 4-1). The resulting distances were used as continuous predictors of narwhal response to vessel traffic. To account for the orientation of the vessel relative to the substrata, vessels that were nearing the substrata (angle >270º and <90º) were classified as "Toward the substratum", whereas vessels that were moving away from the substrata (90º< angle <270º) were classified as "Away from the substratum". The interpretation of a vessel moving toward or moving away is therefore not that it departs the actual substratum, but that it is moving away from the substratum, acknowledging that an animal's response to a transiting vessel may vary depending on whether it is being approached by the vessel or is at the stern where the majority of radiated noise is generated. In other words, a vessel does not need to transit through a particular substratum to be recorded as moving away from that substratum. The AIS data preparation was repeated in an identical way for the behavioural and composition dataset, using the BSA centroid as the reference point.

In previous analyses, the potential effects of the vessel were assessed up to 15 km from the SSA substrata or from the centroid of the BSA (Golder 2019). However, following the completion of the analysis of movements and dive behaviour of narwhal equipped with GPS and dive tags (Golder 2020a), effects of vessel exposure on narwhal behaviour were generally captured only up to 5 km from vessels, and often only up to 1-2 km from vessels. That is, narwhal behaviour was generally found to return to no-exposure levels once vessels were 5 km or farther from narwhal. However, to include potential effects with a wider spatial extent, the distance of "potential vessel effects" in the current analyses was defined as 10 km, and vessels found farther than 10 km from the relevant SSA or BSA centroids were considered as "no vessels within 10 km".

PATH: I:\2016\1663724\Mapping\MXD\23000_2019BruceHeadProgram\1663724_23000_04_Fig4_1_AnglesDistancesAISData_Rev0.mxd PRINTED ON: 2020-08-28 AT: 10:16:04 AM



LEGEND

- ★ OBSERVER LOCATION
- SAMPLE AIS VESSEL LOCATION
- STRATIFIED STUDY AREA (SSA) SUBSTRATA CENTROID
- ANGLE BETWEEN HEADING AND SUBSTRATA
- DIRECTION TO SUBSTRATA
- SAMPLE AIS VESSEL HEADING
- WATERCOURSE
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

SUBSTRATA LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. HYDROGRAPHY DATA BY EAGLE MAPPING (2005), RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE, MAY 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
VESSEL DISTANCE AND TRANSITING ANGLE RELATIVE TO SURVEY SUBSTRATA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	4-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

4.4.1.3 Relative Abundance and Distribution (RAD) Data

For each RAD count within a given substratum, AIS data was retrieved for each vessel present in the study area, including information on course, heading, and distance, and whether the vessel was moving toward or away from the substratum's centroid (recorded to the nearest time stamp). The data were then filtered using a temporal criterion: vessels whose positions were recorded more than 15 minutes either before or after each substratum's count were removed from analysis, leaving only relevant AIS data for the modeling. In addition, a spatial criterion was added – vessels that were more than 10 km away from a centroid were not considered to affect relative abundance or distribution of narwhal. This spatial filter corresponds to the longest distance between a vessel entering the original SSA extent (i.e., substrata A-I) and a centroid of the furthest substratum (e.g., when a vessel is at the northern boundary of the SSA and the centroid of I3). Since previous work (Smith et al. 2017) only considered vessel traffic effects when vessels were entering the SSA, the restriction of vessel distance to 10 km from a centroid enabled comparison between the 2017 results and previous findings. Data filtration was performed similarly for the behavioural and composition data. All data collected during conditions of impossible sightability were removed from the analyses.

4.4.1.4 Group Composition and Behavioural Data

Similar to the process described above to allocate vessel distance and angle relative to SSA centroids, group composition and behavioural data were also allocated vessel distance and angle, using the centroid of the BSA instead of the SSA centroids. Note that the BSA centroid used for 2014-2016 data differed from the centroid used for 2017 and 2019 data, as detailed in Section 4.4.1.1.

4.4.1.5 Anthropogenic Data

In addition to the anthropogenic effects of vessel traffic, other anthropogenic activities considered in the multi-year analysis were 'small vessel traffic' and 'hunting activity'. Hunting activity included discrete shooting events recorded by observers at the observation platform throughout 2014-2017 and 2019 sampling. In addition, in 2019, shooting events as recorded using Wildlife Acoustics SM4 recorders were added to the dataset. For each RAD survey and group composition and behaviour sighting, the time since last shooting (in minutes) was calculated. The period between the onset of each RAD survey and a discrete shooting event was classified as 'no hunting activity`. Small vessel traffic was expressed as the number of small vessels present within the SSA and BSA during the RAD and group composition/behaviour surveys, respectively.

In previous analyses, the effects of hunting were assessed up to 12.5 h from the last shooting event (Smith et al 2017, Golder 2019). However, following the completion of the analysis of the combined 2014-2017 dataset (Golder 2019), the temporal extent of the effects of hunting on narwhal counts per substratum were assessed. Specifically, multiple comparisons (with Dunnett-adjusted *P* values) were performed to estimate at which time post-shooting the estimated response values became not significantly different from values predicted when no hunting occurred for at least 12.5 h prior to sampling. The comparisons were restricted to 2 h post shooting. The results indicated that narwhal counts at 0 min, 15 min, and 30 min post a shooting event were significantly different from no-hunting counts (P values of <0.001, <0.001, and 0.021, respectively). However, starting at 45 min post shooting, narwhal counts were not significantly different from no-hunting counts until the end of the 2 h period of assessment ($P>0.05$). That is, narwhal counts post-hunting differ from no-hunting counts only until 45 min post-hunting. However, to provide a conservative period of time, to include any potential longer-lasting effects, the period of "potential hunting effects" in the current analyses was defined as 3 h, and shooting events that occurred more than 3 h prior to a survey of a substratum were considered as "no hunting".

4.4.1.6 Environmental Data

Following the approach used by Smith et al. (2017), the continuous tide elevation estimates were used to calculate the change in elevation between consecutive intervals. The tide values were categorized into four levels - low slack, flood, high slack, and ebb. If the change in elevation within a 5 min interval was ≤0.01 m on either side of the lowest elevation level for a given cycle, the tide was considered to be “low slack”. An increasing elevation with change in elevation >0.01 m was considered “flood”. If the change in elevation within a 5 min interval was ≤0.01 m on either side of the highest elevation level for a given cycle, the tide was considered to be “high slack”. A decreasing elevation with change in elevation >0.01 m was considered “ebb”.

4.4.1.7 Acoustic Data

Acoustic recordings were analyzed to determine the times of hunting events (gunshots) at the Bruce Head hunting camp. Kaleidoscope Pro analysis software was used to make an automated classifier to identify gunshot events but the results proved unsatisfactory. The gunshots did not contain identifiable frequencies but only broadband noise signals, and the software could only rely on changes in the overall dB level to identify events. Subsequently, any deviation from background noise levels in the recordings could be flagged as a potential gunshot, resulting in many false positive events that had to be visually checked. The alternative and preferred analysis approach was to visually assess the recordings using Kaleidoscope Pro and manually note the times of gunshot events. The gunshot events were readily identifiable during visual assessment (Figure) and could be checked by listening to the same event, which could also be accompanied by the sound of the hunter’s vessel retrieving the animal. Comparison of the 24 and 48 kHz sampling rate recordings determined that the lower sampling rate was sufficient for the identification of gunshots and would be the preferred method for subsequent surveys due to its lower power consumption rate.

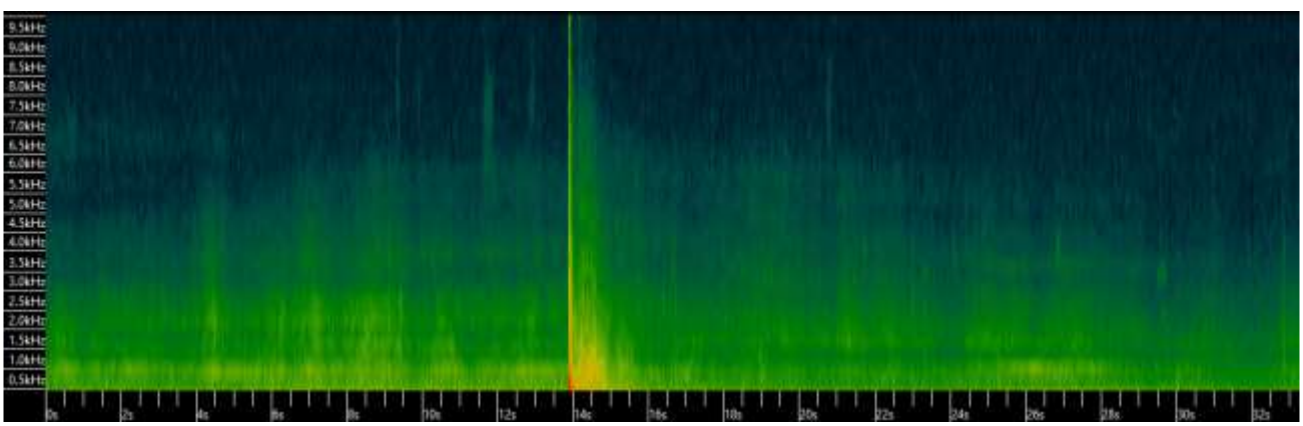


Figure 4-2: Example gunshot event with time scale on X axis and acoustic frequency on Y axis. Warmer colours are for louder sounds - note echoes after initial shot.

4.4.1.8 Data Filtering

Data omitted from the multi-year analysis of RAD data included:

1) Sightings collected during periods of 'impossible' sightability and cases with Beaufort scale value of 6 or higher (742 cases representing 2.2% of total RAD counts). These accounted for a combination of high sea state, glare, fog, or ice cover, and therefore had to be removed from the modeling dataset.

2) Cases with 200 or more narwhal within substratum (3 cases, <0.01% of total RAD counts) – these were removed to resolve model convergence issues.

Note that some of these cases overlapped. For example, in 18 substratum counts, sightability was "impossible" and Beaufort scale value was 6 or higher.

Data omitted from the multi-year analysis of group composition and behaviour data included:

1) Observations collected during periods of 'impossible' sightability (eight observations representing <0.2% of total observations).

2) Cases where group size was >20 narwhal (18 cases overall representing 0.3% of total observations). Groups of >20 narwhal were very rare (observed 3, 5, 0, 1, and 9 times in 2014, 2015, 2016, 2017, and 2019, respectively). Group size was used as a continuous covariate in the analysis of group composition, spread, formation, direction, speed, and distance from shore. These large group sizes resulted in being influential cases, skewing model results. Therefore, these 18 cases were removed from analysis, to capture the patterns of the overall dataset.

4.4.2 Statistical Models

4.4.2.1 Updates to Analytical Approach

The following changes were made to the analytical approach used in 2019 (Golder 2019). These changes were applied to the entire five-year dataset, and therefore do not affect the ability to assess differences between sampling years.

- Vessel effects were considered when vessels were within 10 km from SSA and BSA centroids, as opposed to the 15 km spatial extent that was used previously, as detailed in Section 4.4.1.2.
- Presence of multiple vessels within the spatial extent of effect (10 km) was incorporated into the model. While in previous analyses, cases with multiple vessels in the spatial extent of effect were removed from analysis, the analyses presented in this report were applied to the full dataset. To accommodate this change, specific vessel-related variables (distance, relative position, and direction within Milne Inlet) were set to describe the vessel that were nearest to the SSA / BSA, and the variable that previously was coded to identify whether vessels were present or absent was recorded, to describe whether there were no vessels, where there was a single vessel, or two or more vessels within the spatial extent of effect.
- The predictor variable "tide" was changed from the continuous variables describing elevation and change in elevation, as used in Golder (2019), to a categorical variable, with the following values: low slack, flood, high slack, and ebb, as described in Section 4.4.1.6.

- In the previous analyses (Smith et al 2017; Golder 2019), the effects of hunting were assessed up to 12.5 h from the last shooting event. In the current analysis, the temporal effects of hunting were only considered up to 3 h, as detailed in Section 4.4.1.5.
- Small vessel effects – in previous analysis, the number of small vessels within the SSA was used as a continuous predictor variable (Golder 2019). Since in 2019 it was often difficult to observe small vessels that were driving directly below the cliff due to the relocation of the observation platform, it was deemed that counts of small vessels may be biased. This variable was therefore simplified to a present/absent categorical variable.
- In previous analysis, cases where a landmass was found in the line of sight between vessels and the SSA/BSA centroids were removed from analysis (Golder 2019). In the current analysis, these cases were retained, due to these two considerations:
  - this data filtering step was not performed in other behavioural analyses (Golder 2020a), and retention of data would therefore better align the two studies, and
  - the reduction of the spatial extent of effects to 10 km reduced the occurrence of landmasses between vessels and SSA/BSA centroids, thereby becoming less of a concern.

4.4.2.2 Fixed Effect Predictors

For RAD analysis, a plot showing the response variable (i.e., narwhal count per substratum) in response to distance from vessels was constructed using the raw data for each analyzed response variable. For this plot, the values of the response variable were summarized for each combination of south- or northbound vessel, vessel moving toward or away from the substratum (or the BSA), and 0.5 km distance bins. For behavioural and group composition data, a similar plot was constructed, however the response variable was not summarized, and was instead shown as-is. The plot provided a visual tool to identify potential trends in the response variable in relation to vessel predictor variables.

The analyses detailed in this report included two components: 1) RAD analysis; and 2) group composition and behavioural data analyses. Both RAD and group composition/behavioural data were analyzed using the same host of fixed-effect predictors. While evaluating the effect of vessel traffic (i.e., shipping) was the focus of the analysis, it was important to include other potential explanatory variables in the model to account for spatial and temporal trends. The list of predictor variables used for all analyses included:

1) Glare (within SSA strata or BSA, as applicable) — categorical variable with the following categories: None (N), Low (L), Moderate (M), and Severe (S).
2) Beaufort scale (within SSA strata or BSA, as applicable) — for the RAD, it was used as categorical variable, with categories ranging from 0 to 5. For the BSA, Beaufort scale values of 4 of greater were combined into a single bin of “4+”. These accounted for 279 cases in the dataset (5%).
3) Tide – categorical variable with the following categories: "low slack", "flood", "high slack", and "ebb", as detailed in Section 4.4.1.6.
4) Distance from vessel — continuous variable (in km) calculated between vessel location and each of the SSA substratum (and BSA) centroids.

5) Relative position between vessel and centroids — whether the vessel was heading toward or away from the SSA/BSA centroid.

6) Vessel direction within Milne Inlet — categorical variable with two categories: 'northbound' and 'southbound'.

7) Interaction between vessel distance and relative position of vessel.

8) Interaction between vessel distance and vessel direction.

9) Interaction between vessel direction and relative position of vessel.

10) Interaction between vessel distance, vessel direction, and relative position of vessel.

11) Vessel presence within 10 km of the substratum/BSA centroid — categorical variable with three categories: 'no vessel present within 10 km', 'one vessel present within 10 km', and '2 or more vessels present within 10 km'.

12) Time since last shot fired — continuous variable (in minutes).

13) Whether hunting occurred within a pre-defined window prior to a sighting — categorical variable with two categories: 'hunting occurred' and 'no hunting occurred'. For both RAD and behaviour and composition analyses, 3 hours was selected as the pre-sighting cut-off limit for a hunting activity, as detailed in Section 4.4.1.5.

14) Presence of small vessels in the SSA during the observation — categorical variable (absent or present).

15) Day of year — continuous variable, where January 1 of each year is assigned a value of 1. Only used for RAD analyses, since preliminary visual data assessments did not identify relationships between group composition and behaviour response variables and day of year.

16) Year — categorical variable with five categories: 2014, 2015, 2016, 2017, and 2019.

The effects of day of year, time since last shooting event, and distance between vessels and centroids were expressed as polynomials whenever necessary, as determined by visual examination of the data and preliminary modeling. All polynomial terms were modeled as orthogonal, rather than raw polynomials, to assist with numerical stability; hence, the coefficients reported for polynomial model effects are not directly interpretable. The list of fixed effects and their degrees of freedom are provided in the results of each component for transparency. All continuous variables were standardized by subtracting the mean and dividing by the standard deviation of the variable.

4.4.2.3 Relative Abundance and Distribution

Narwhal RAD data collected in the SSA were analyzed as the total number of narwhal observed in each substratum during each RAD count completed throughout the five years of sampling. The generalized mixed linear model with a zero-inflation component evaluated how the relative abundance of narwhal (expressed as total narwhal count per substratum) was affected by the various predictor variables. In addition to the variables listed in Section 4.4.2.1, the RAD model included also the effects of stratum (A to J) and substratum (1, 2, or 3). Note that substratum was not nested within stratum, since substratum was treated as a proxy for distance between observer and each sampled substratum.

The selected modelling framework was a zero-inflated negative binomial model with a random effect of day (where each sampling day within the five-year period had a unique value) and a spatial autocorrelation within each sampling day. The spatial autocorrelation approach used the built-in spatial autocorrelation structure provided by the glmmTMB package (Brooks et al. 2017), which used substratum centroid UTM positions to estimate the spatial autocorrelation between data points. The zero-inflation portion of the model was modelled to depend on stratum, substratum, and Beaufort scale, thus reflecting the unequal distribution of zero counts between different categories of these variables. In previous analyses (Golder 2019), the effect of survey year was also included in the zero inflation portion of the RAD model. However, when preliminary modeling was performed using the combined 2014-2017 and 2019 data, these models did not converge, and the effect of year was removed from the zero inflation component. Likelihood ratio tests (alpha of 0.05) were used to determine the importance of the zero-inflation component of the model. The full zero-inflated model was tested relative to a zero-inflated model with an intercept-only zero-inflation component and relative to a negative binomial model without zero-inflation.

The selected analytical approach allowed for analysis of count data with a high occurrence of zeroes, while specifying an explicit spatial autocorrelation — i.e., accounting for the fact that narwhal are not randomly distributed and that counts in adjacent substrata will likely be more similar than counts in spatially segregated substrata. The model was used for inference of statistical significance based on *P* values of effects. Variable significance was assessed using type II *P* values (Langsrud 2003). Type III *P* values, which are commonly used in statistical analysis, allow for testing the statistical significance of main effects in the presence of significant interactions. However, when the interactions are significant, the effect sizes associated with the effects are of more interest than the *P* values of the main effects (e.g., Matthews and Altman 1996). In contrast, when the interactions are not significant, the type II tests have more power than type III tests (Lewsey et al. 2001). That is, a model with type II *P* values provides a more powerful test for main effects in the absence of a significant interaction, and no loss of information in the presence of a significant interaction, since the *P* values of the main effects are of no interest. In addition to testing of model effects using Type II *P* values, model coefficients were also reported, using treatment contrasts and Type I *P* values, which allows assessment of each slope relative to the intercept.

For effects that were found to be statistically significant, population-level model predictions (i.e., model prediction for a typical survey day) were plotted against observed data to visualize the estimated relationships between narwhal counts and the various explanatory variables. In cases where shipping effects were not statistically significant but effect sizes were large (suggesting low statistical power), predictions were still produced and plotted and results discussed. Since the model contained multiple predictor variables, the visualization of predictions relative to specific variables of interest required setting the other predictor variables to a constant value. These predictor values were selected based on observed narwhal counts (so that narwhal counts were close to the overall mean of narwhal/substratum values), frequency of occurrence (e.g., the majority of the data were collected in the absence of vessels or shooting events), or, when possible, their average values. The following predictor values were used to visualize model predictions: stratum F, substratum 2, Beaufort scale of 2, survey year 2017, day of year 227 (15 August), tide level ‘flood’, and glare value ‘N’.

If significant effects of distance from vessel were found, multiple comparisons (with Dunnett-adjusted *P* values) were performed to estimate at which distance the estimated response values became significantly different from values predicted when no vessels were present within 10 km. This was performed for both scenarios of a single vessel within 10 km from the substratum and 2+ vessels within 10 km from the substratum. In addition, the effect of 2+ vessels (where the nearest vessel was at distance of 0 km) was tested against the effect of a single vessel (also at distance of 0 km), to assess whether passage of multiple vessels is significantly different from the passage of a single vessel. All comparisons were made using the package emmeans (Lenth 2020) in R v.3.6.1 (R 2019). If a significant effect of vessel presence was found (categorical variable with three levels – "no vessels", "a single vessel within 10 km", and "2+ vessels within 10 km"), a comparison of the effect of 2+ vessels (where the nearest vessel was at distance of 0 km) was tested against the effect of a single vessel (also at distance of 0 km), to assess whether passage of multiple vessels is significantly different from the passage of a single vessel. All comparisons were made using the package emmeans (Lenth 2020) in R v.3.6.1 (R 2019).

All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v.3.6.1 (R 2019). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019) in R v. 3.6.1 (R Core Team 2019). The pseudo R^2 values (Nakagawa et al. 2017) were reported for marginal portions of the model, which provided an estimate of the variability explained by the fixed effects.

4.4.2.4 Group Composition and Behaviour

Narwhal group composition and behavioural data were plotted as time series, and also as a function of group size in relation to proximity and relative position of vessels.

Following the classification used in 2016 (Smith et al. 2017), groups of known composition (i.e., where no 'unknown' life stages were part of the group) were classified using the following six categories:

- Group 1—no observed tusks (adults or juveniles without tusks), no calves or yearlings
- Group 2—no observed tusks (adults or juveniles without tusks), yes calves or yearlings
- Group 3—mixed tusks (adults or juveniles, with and without tusks), no calves or yearlings
- Group 4—mixed tusks (adults or juveniles, with and without tusks), yes calves or yearlings
- Group 5—yes tusks (adults or juveniles with tusks), no calves or yearlings
- Group 6—yes tusks (adults or juveniles with tusks), yes calves or yearlings
- Other—all other groups

The combined 2014–2017 and 2019 data were used to construct a set of models to describe the variables of interest, similar to those identified in Golder (2019). The models developed for analysis of group composition and behavioural data examined changes in group size, group composition, spread, formation, direction, speed, and distance from shore. The explanatory variables used for these analyses were similar to those used for RAD models (see Section 4.4.2.2). The models were examined for significant effects, and estimated predictions were plotted against the explanatory variables to visualize patterns. All models had a random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) to account for the inter-day variability in group sizes. Since observations were often close in time, autocorrelation for irregular time steps was added to the models. Similar to the methods detailed for the RAD analysis (Section 4.4.2.3), the models were used for inference of statistical significance based on *P* values of coefficients, and population-level model predictions (i.e., predictions made for a typical sampling day) were plotted against observed data to visualize the estimated relationships between narwhal group composition and behaviour and the various explanatory variables.

Similar to the RAD model, predictions of group composition and behaviour for plotting model results were calculated on a grid of constant values of all other predictors (year 2017, group size of 3 narwhal, tide level ‘flood’, no vessel present, no hunting event occurred, no small vessel present, no glare, and a Beaufort scale value of 1).

Similar to the RAD analysis (Section 4.4.2.3), if significant effects of distance from vessel were found, multiple comparisons were performed to estimate at which distance the estimated response values became significantly different from values predicted when no vessels were present within 10 km. This was performed for both scenarios of a single vessel within 10 km from the BSA and 2+ vessels within 10 km from the BSA. In addition, the effect of 2+ vessels (where the nearest vessel was at distance of 0 km) was tested against the effect of a single vessel (also at distance of 0 km), to assess whether passage of multiple vessels is significantly different from the passage of a single vessel. All comparisons were made using the package emmeans (Lenth 2020) in R v.3.6.1 (R 2019).

All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v.3.6.1 (R 2019). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019) in R v. 3.6.1 (R Core Team 2019). The pseudo R^2 values (Nakagawa et al. 2017) were reported for marginal portions of the model, which provided an estimate of the variability explained by the fixed effects.

4.4.2.4.1 Group Size

The analysis of group size included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). A generalized mixed linear model was used to estimate the effect of the various fixed variables on group size. Group size was assumed to have a truncated Poisson distribution (where truncation was necessary, since no zeroes were possible in the data), and a random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in group sizes.

4.4.2.4.2 Group Composition

4.4.2.4.2.1 Presence of Tusks

The analysis of presence of tusks in observed groups included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on presence of tusks. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in presence of tusks.

4.4.2.4.2.2 Presence of Calves or Yearlings

The analysis of presence of calves or yearlings in observed groups included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was used as a covariate in the model. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on presence of calves or yearlings in the observed groups. A random intercept of day of survey (unique value for each day of survey throughout 2014–2019) was used to account for the inter-day variability in presence of calves and yearlings.

4.4.2.4.3 Group Spread

The analysis of group spread (loose vs tight groups) included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group spread. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in group spread.

4.4.2.4.4 Group Formation

The analysis of group formation was simplified to a logistic regression by analysing whether the observed group formation was parallel or not (instead of analysing each individual observed formation). Since parallel formation was by far the most common (64% of all data), the parallel formation was assumed to be the baseline formation. Therefore, the logistic analysis will provide insight into the effect of the predictor variables and deviations from the baseline parallel formation.

The analysis of group formation included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group formation. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in group formation.

4.4.2.4.5 Group Direction

The analysis of group direction was simplified to a logistic regression by removing cases of west- or east-travelling groups (a total of 163 groups representing 3% of the data). The resulting dataset contained only north- or south-travelling groups. The analysis of group direction included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group direction. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in group direction.

4.4.2.4.6 Travel Speed

The analysis of travel speed was performed using two logistic models — one of fast vs medium speeds, and another of slow vs medium speeds. In both cases, medium travel speeds were assumed to be the baseline values, since medium travel speeds were the most common (57% of the data). A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group travel speed. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in speed. Both the analyses of travel speed included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship), in addition to group size that was used as a covariate.

4.4.2.4.7 Distance from Bruce Head Shore

The analysis of whether narwhal groups were close to shore (<300 m) or far from shore (>300 m) included all predictor variables listed in Section 4.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group distance from shore. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019) was used to account for the inter-day variability in distance from shore.

4.4.3 Power Analysis

To assess the statistical power of the analyses performed in this report, a separate power analysis was performed for each model. The power analysis was performed using simulations that quantified the relevant model's statistical power to detect various effect sizes. The resulting power curves were presented for each model. Refer to Appendix E for detailed methods and results of the power analysis.

5.0 RESULTS

5.1 Observational Effort and Environmental Conditions

Each yearly monitoring program at Bruce Head (2014–2017 and 2019) was timed to extend over an approximate five-week period, coinciding with the open-water season (Table 5-1; Figure 5-1). In general, the study area was ice-free during each program, with occasional presence of drifting ice floes in the SSA. Survey effort varied between years (Table 5-1), largely due to changing weather conditions and the number of monitoring shifts used each year. For example, survey effort was lower in 2017 than in previous years due to only having a single daily 10 h monitoring shift, while previous years consisted of two daily rotating 8 h shifts. In 2019, two daily shifts were resumed, with each team monitoring for a total of 8 h.

Table 5-1: Number of narwhal and vessel transits recorded during RAD survey effort (2014–2017 and 2019)

Statistic	Survey year					Total
	2014	2015	2016	2017	2019	
Shipping season extent	8 Aug–3 Sep	3 Aug–4 Sep	28 Jul–3 Sep	2 Aug–17 Oct	18 Jul–30 Oct	-
Survey dates	3 Aug–5 Sep	29 July–5 Sep	30 July–30 Aug	31 July–29 Aug	06 Aug–01 Sep	-
No. of active survey days	23	29	27	26	26	131
No. of survey days lost to weather	14	9	11	2	3	36
No. of observer hours (total)	103.2	148.7	159.3	97.3	151.5	660.0
Average daily survey effort (h)	7.8	10.8	11.9	6.2	11.1	9.3
No. of attempted RAD surveys	179	314	321	160(1)	288	974
No. of complete RAD surveys	166	313	311	109	169	1068
Number of RAD surveys with 0 narwhal counts(2)	74	164	127	35	71	471
No. of narwhal (total)	10,463	14,599	28,309	11,862	19,210	84,443
No. of narwhal excluding ‘impossible’ sightability	10,463	14,599	28,309	11,831	19,200	84,402
No. of narwhal excluding ‘impossible’ sightability, standardized by effort (total narwhal / total h)	101.4	98.2	178.0	121.8	126.7	128.3[4]
No. of vessel transits during RAD effort	7	11(3)	21(3)	22	32(3)	93
No. of RAD surveys with >1 vessel transiting	2	0	3	4	11	20

(1) = one survey out of the total 160 surveys was omitted from all other counts and analyses due to high chance of double-counting animals. All other values shown for 2017 in this table and elsewhere exclude this survey.

(2) = non-complete surveys were included in this calculation

(3) = counts of vessel transits differ from those presented in Table 5-2 due to transits occurring outside of a RAD count or the vessel being farther than 10 km from relevant substrata during the RAD count.

(4) Total number of observed narwhal, divided by total effort

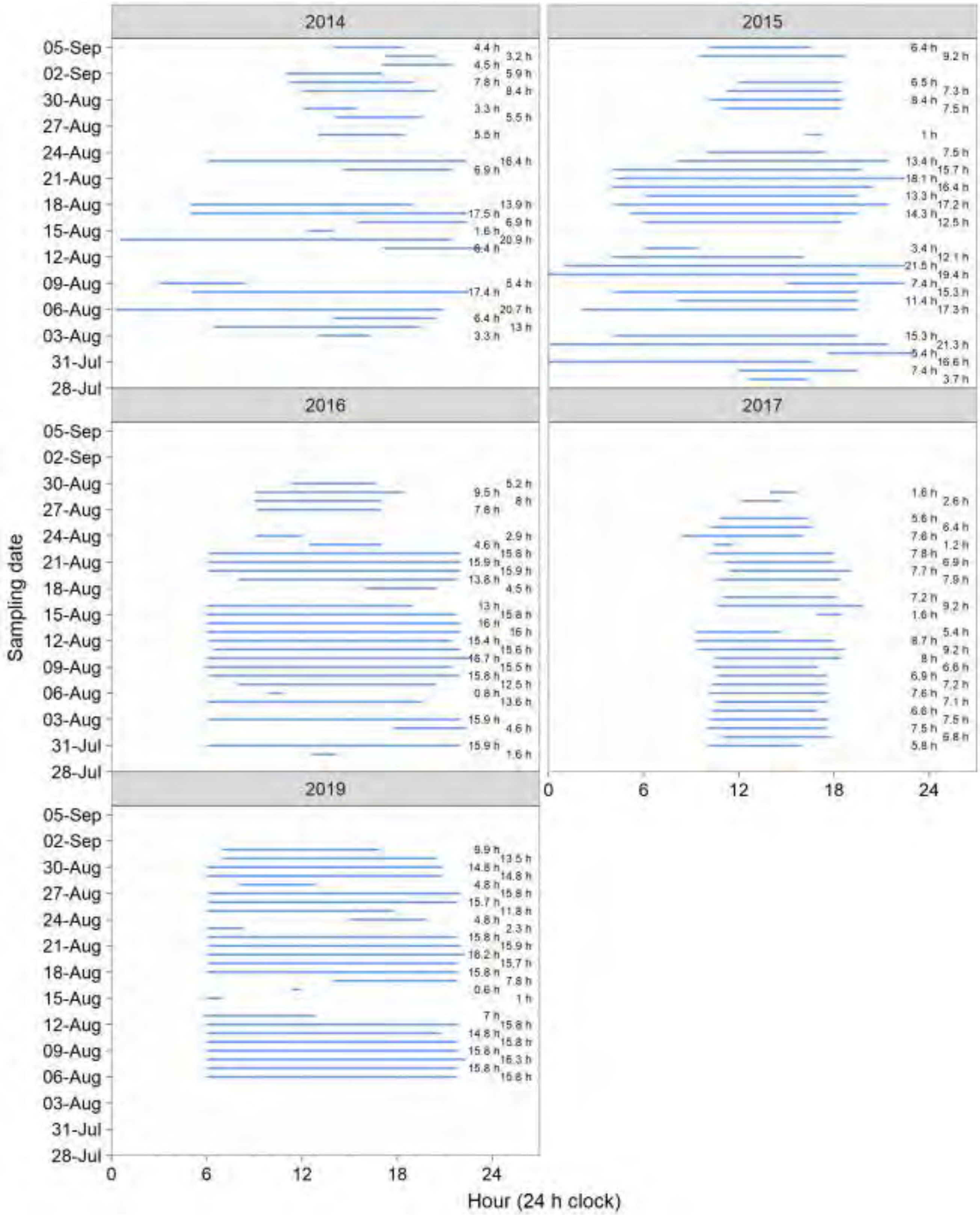


Figure 5-1: Observer effort (h) by survey day (2014–2017, 2019)

Across the five years of data collection, sightability was shown to decrease with increasing wind levels, and with increasing stratum distance relative to the observation platform (e.g., substratum 3 was generally associated with reduced sightability compared to substratum 1; Figure 5-2). All sightings made during 'impossible' sighting conditions or during wind conditions of Beaufort value 6 or higher were removed from the multi-year analysis, equivalent to 453 rows of RAD data (1.4% of the total 2014–2017 and 2019 dataset).

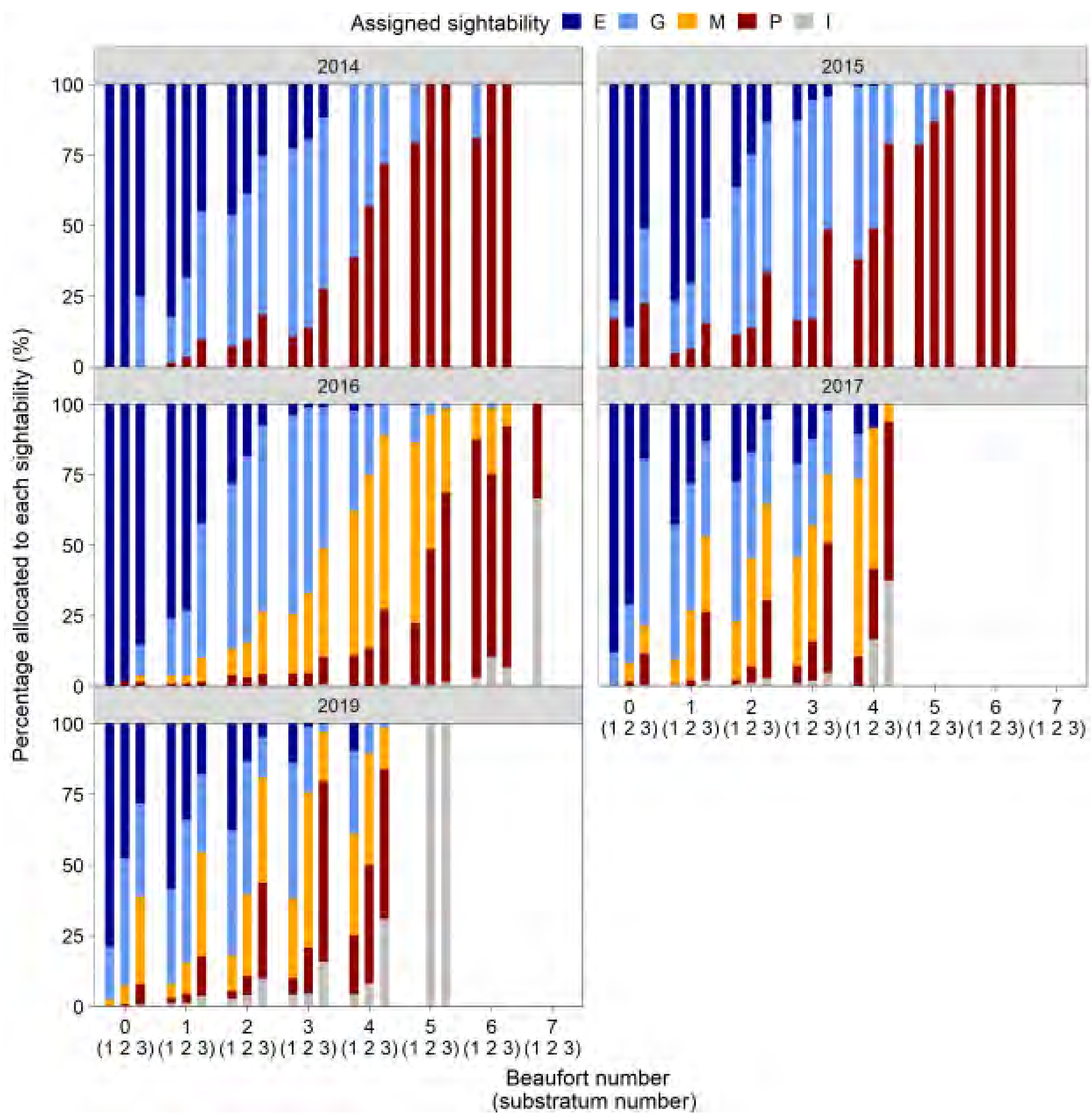


Figure 5-2: Sightability conditions during the 2014–2017 and 2019 RAD surveys in the SSA based on Beaufort Wind Scale and substratum location (plotted by year): Excellent, Good, Moderate, Poor, Impossible

5.2 Vessel Transits and Other Anthropogenic Activity

5.2.1 Baffinland Vessels and Other Large/Medium-Sized Vessels

The total number of one-way vessel transits that entered the SSA during the full shipping season and during the Bruce Head monitoring period each year is summarized in Table 5-2 and Figure 5-3. In 2019, sighting data were recorded during 55% of all vessel transits that occurred during the survey period and consisted primarily of Project-related bulk (ore) carriers (32 unique vessels, 62 one-way transits; Table 5-2; Appendix B). Ore carriers accounted for 59%, 77%, 73%, and 83% of total one-way transits in 2015, 2016, 2017, and 2019, respectively (no ore carriers were present in 2014). Other large Project-related vessels included general cargo vessels and fuel tankers. No passenger vessels were recorded in the SSA in 2019 and other, non-Project-related vessels that entered the SSA included one National Defence vessel (*Canadian Warship 332*).

Recorded tracklines of all vessel transits through the SSA during the full extent of the shipping seasons (2014–2017 and 2019) are presented in Figure 5-4. Recorded tracklines of vessel transits during the 2019 survey period specifically are presented in (Figure 5-5).

Table 5-2: Number of vessel transits in SSA per survey year

Survey Year	No. of 1-way Transits in SSA (No. of Project-related Transits)		No. and (%) of 1-way Transits Recorded by Observers during Bruce Head Survey Period
	Full Shipping Season	During Bruce Head Survey Period	
2014	13 (5)	13 (5)	7 (54%)
2015	22 (20)	22 (20)	13 (59%)
2016	56 (49)	47 (40)	24 (51%)
2017	154 (150)	59 (55)	22 (37%)
2019	240 (238)	75 (73)	41 (55%)
Total	485 (462)	216 (193)	107 (50%)

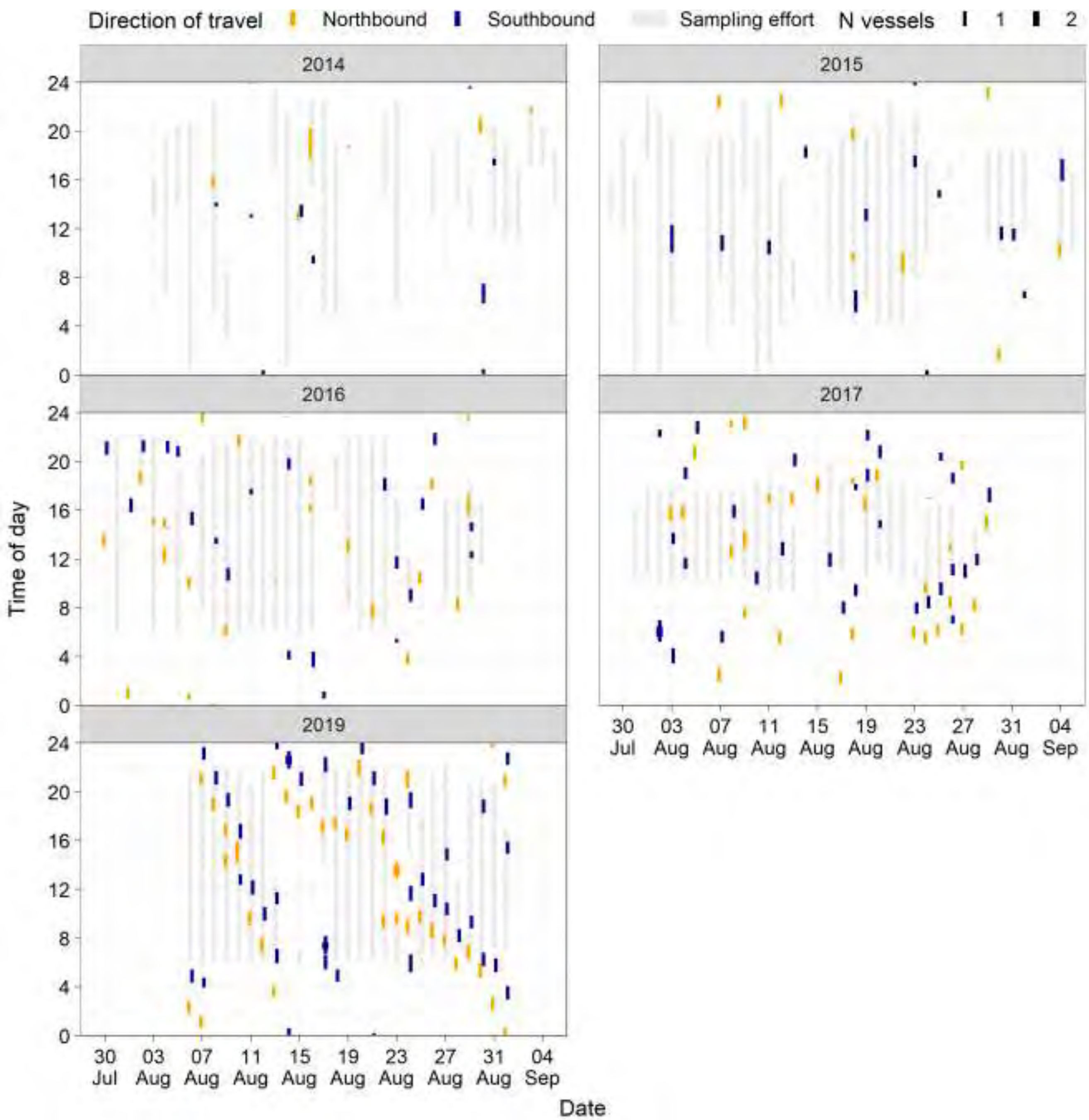
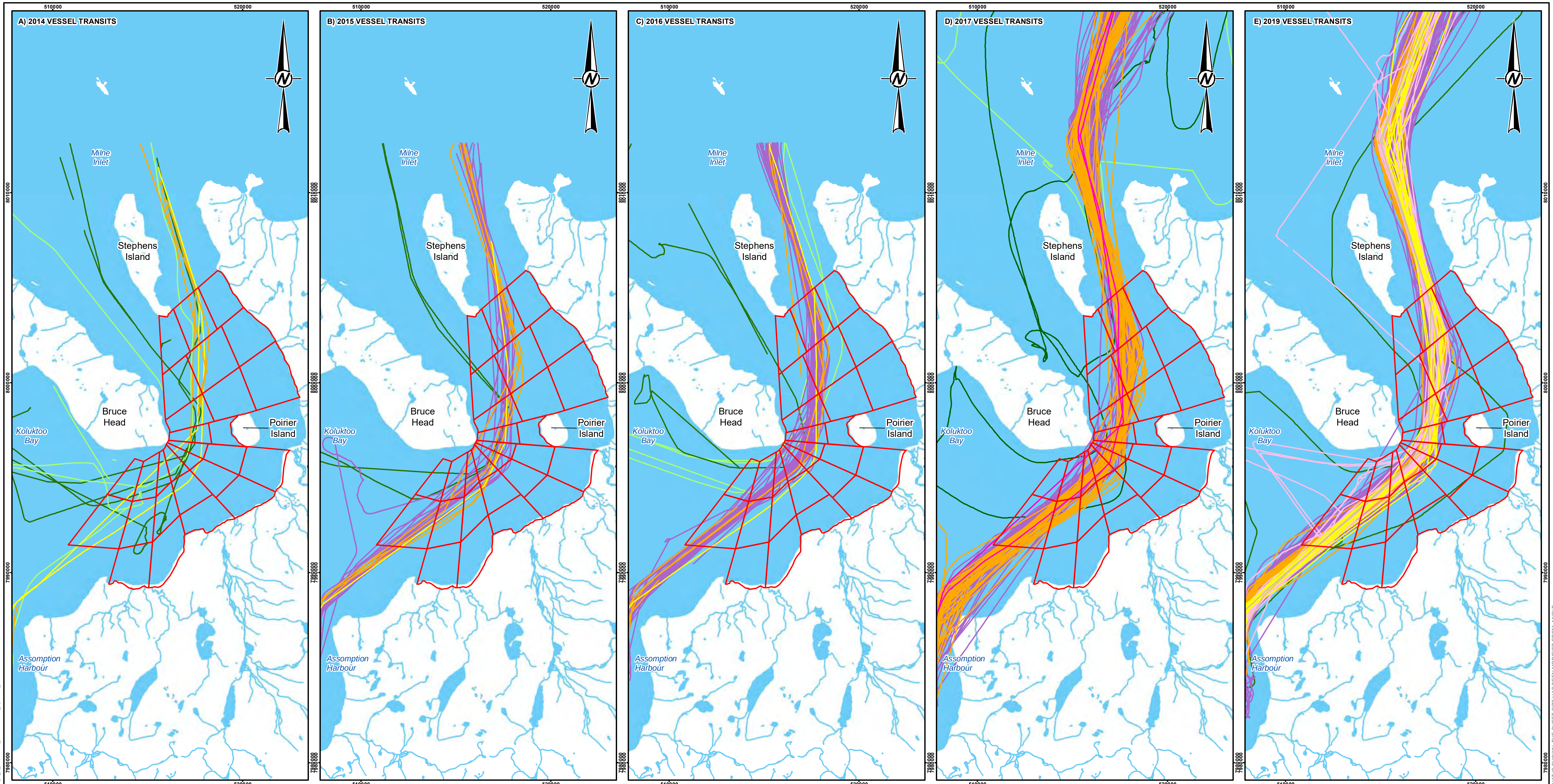


Figure 5-3: Daily summary of vessel transits in SSA with associated survey effort. Grey boxes indicate daily monitoring periods and correspond to observer survey effort shown in Figure 5-1



LEGEND

WATERCOURSE

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

- BULK (ORE) CARRIER
- CARGO CARRIER
- FUEL TANKER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)

MEDIUM VESSELS

- CARGO CARRIER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)

STRATIFIED STUDY AREA (SSA) SUBSTRATA

WATERBODY

0 5 10

1:200,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE

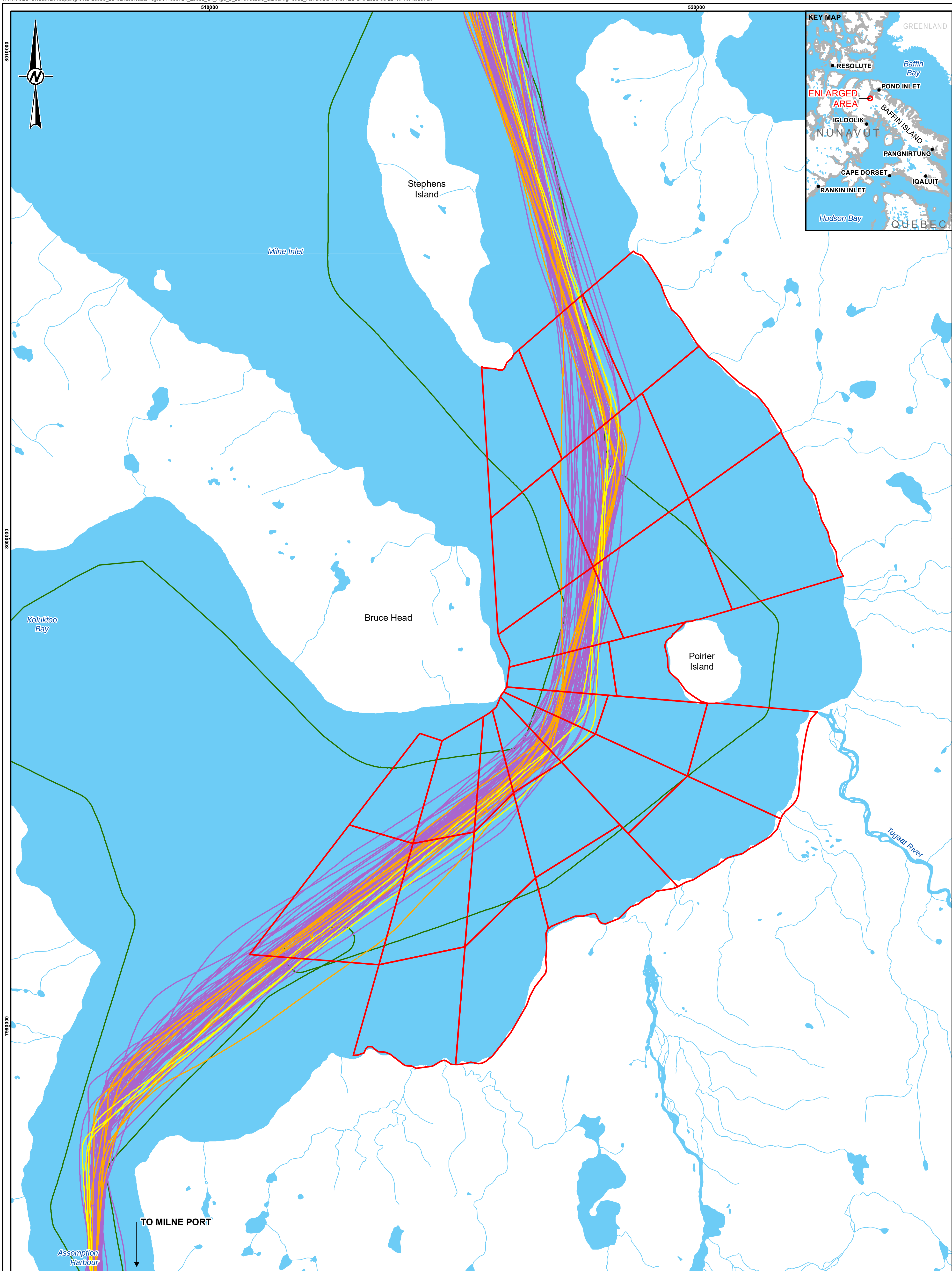
TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA (2014-2017, AND 2019) DURING FULL SEASON SHIPPING

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	5-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

PATH: I:\2016\1663724\Mapping\MXD\23000_2019BruceHeadProgram\1663724_23000_04_Fig5_4_MilneInlet_VesselTraffic_byClass_Rev0.mxd PRINTED ON: 2020-08-28 AT: 10:18:42 AM

PATH: I:\2016\1663724\Mapping\MXD\23000_2019BruceHeadProgram\1663724_23000_04_Fig5_5_2019Vessels_SamplingPeriod_Rev0.mxd PRINTED ON: 2020-08-28 AT: 10:18:00 AM



LEGEND

WATERCOURSE

STRATIFIED STUDY AREA (SSA) SUBSTRATA

WATERBODY

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

BULK (ORE) CARRIER

CARGO CARRIER

FUEL TANKER

OTHER (NON-PROJECT RELATED)

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

SUBSTRATA LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. HYDROGRAPHY DATA BY EAGLE MAPPING (2005), RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE, MAY 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA DURING 2019 SURVEY (6 AUG TO 1 SEP 2019)

CONSULTANT

GOLDER

YYYY-MM-DD	2020-08-28
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	23000-04	0	5-5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

Vessel speeds were plotted by vessel type for each year during the five years of data collection (Figure 5-6). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route has been in place since 2017. In general, Project-related ore carriers transiting rarely exceeded 10 knots during the two years of study since the speed limit has been implemented (mean = 7.9 knots; range = 4.6 to 10.7 knots). Of the 105 ore carrier transits recorded in the SSA during the survey periods of 2017 and 2019, 35 (33%) were at speeds ≥9 knots, and 3 (3%) were at speeds ≥10 knots. Of the 43 ore carrier transits recorded in the SSA during the survey period of 2017, 25 ore carrier transits (58%) were at speeds ≥9 knots and 3 transits (7%) were at speeds ≥10 knots. Of the 62 ore carrier transits recorded in the SSA during the survey period of 2019, only 10 ore carrier transits (16%) were at speeds ≥9 knots and no transits were at speeds ≥10 knots. The average travel speed of Project-related vessels that were not ore carriers (e.g., cargo ships and fuel tankers) in the SSA in 2017 and 2019 was 9.4 knots, ranging from 4.3 knots (*Horizon Star* in 2019) to 14.4 knots (*BBC Volga in* 2017).

Travel speeds of "other", non-Project-related vessels during the 2017 and 2019 study periods ranged from 0.1 knots (*N G Explorer* in 2017) to 17.2 knots (*Canadian Warship 332* in 2019). The number of non-Project-related vessels in the SSA during the study period differed between years, from one vessel (in 2015 and 2019) to four vessels (in 2016). Maximum travel speed of individual vessels within year ranged from 5.3 knots (*Archimedes* in 2017) to 17.1 knots (*Canadian Warship 332* in 2019). Passenger vessels often travelled close to the shore near Bruce Head and occasionally entered Koluktoo Bay. No passenger vessels were observed in 2019.

A total of four medium-sized (50 to 100 m in length) non-Project-related vessels were recorded in the SSA during the five year study period (*Sedna IV* in 2014, *Rosehearty* in 2016, *Galileo G.* in 2016, and *Archimedes* in 2017). *Archimedes* travelled at speeds < 9.0 knots, while the maximum travel speed of the three other vessels ranged from 10 knots (*Sedna IV* in 2014) to 12.0 knots (*Galileo G.* in 2016).

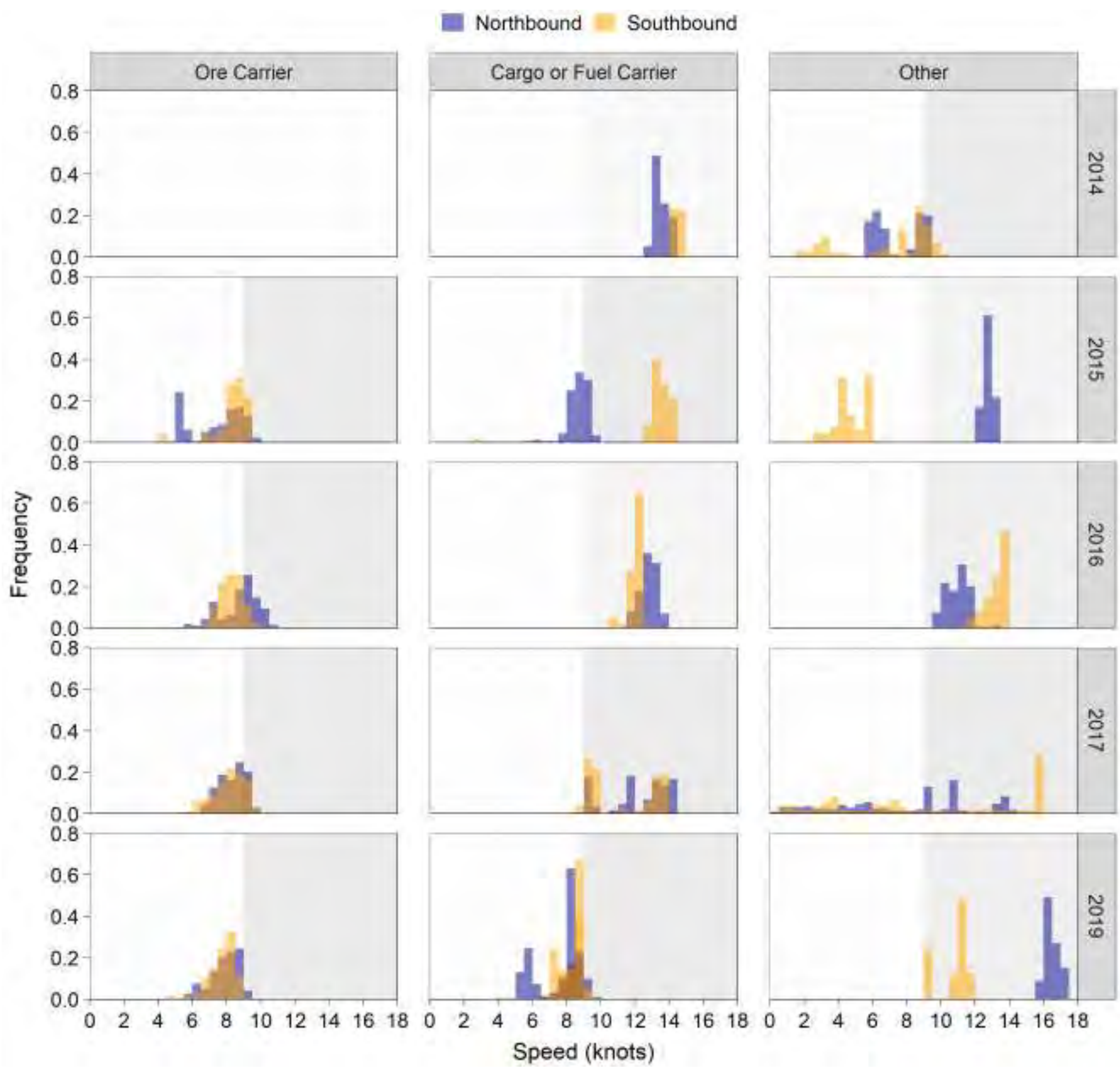


Figure 5-6: Travel speed (knots) of all vessels in the SSA during the 2014–2019 survey periods. Shaded area represents speeds >9 knots

5.2.2 Small Vessels

Small vessels (<50 m in length) recorded in the SSA were mostly aluminum skiffs or canoes with outboard motors, operated by local Inuit for hunting, fishing, and camp access. These vessels were generally passing through the SSA in transit to other locations, although several small vessels were recorded pulling ashore or moored to rocks on the shore below the Bruce Head observation platform.

Few small vessels were recorded in the SSA during active RAD surveying. In each of the sampling years, the majority of RAD surveys (73–85%) had no presence of small vessels within the SSA. Only 12–21% of surveys had one small vessel within the SSA (12% in 2015 and 21% in 2017), 2%–6% of surveys had two small vessels (2% in 2014 and 6% in 2017), only 2015, 2016, and 2019 had three small vessels within the SSA during RAD surveys (<1% of surveys for 2015 and 2016, 2% of surveys in 2019), and only 2019 had four small vessels within the SSA during RAD surveys (1% of surveys).

5.2.3 Other Anthropogenic Activities

The shoreline directly below the observation platform at Bruce Head was an established narwhal hunting site commonly used by local community members. Inuit were often observed camping with tents at the site for multiple days at a time, though others only stopped for several minutes to several hours. During the 2019 field program specifically, the hunting camp was visited or occupied by local hunters during 13 of the 26 total survey days.

The majority of RAD surveys were performed more than 3 h post the last shooting event (76-88% of surveys; Figure 5-7). Where hunting occurred within 3 h prior to surveys, 7-20% of the surveys were performed within one hour post a shooting event, depending on year. Important to note, however, is that monitoring of hunting activity for the full extent of the day (i.e. 24 h) only occurred in 2019 with the introduction of a pair of Wildlife Acoustics SM4 acoustic recorders being set up adjacent to the Bruce Head hunting camp for the purpose of continuously recording all shots fired over the course of the field program.

Generally, shooting events targeted either narwhal or seal. Shooting events in the air were indirectly targeting narwhal as the local Inuit observers explained that the intent was for the bullet to fall on the offshore side of the narwhal, spooking the animal so that it would flee towards the Bruce Head shoreline, closer to the hunters.

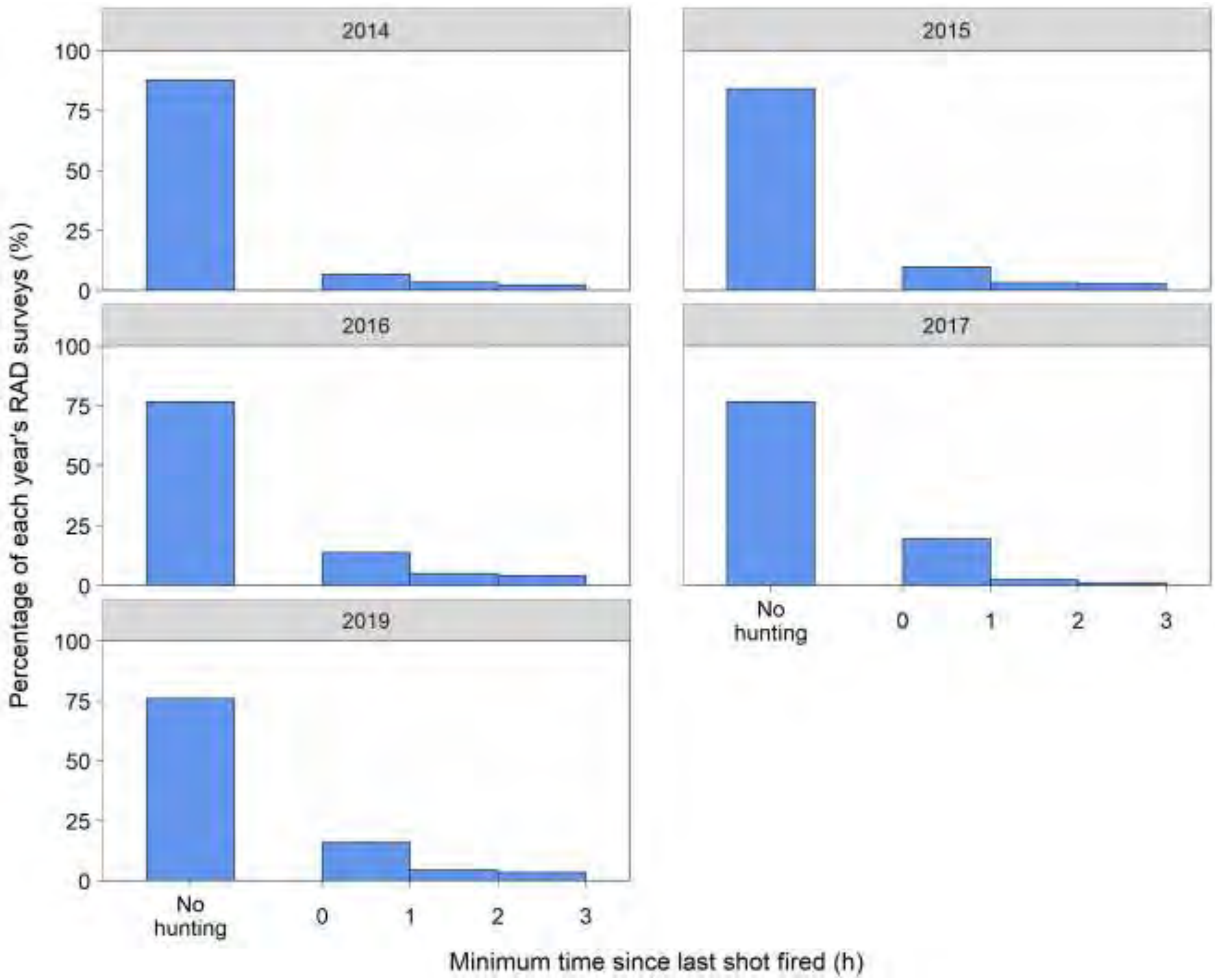


Figure 5-7: Distribution of each year's minimum time since shooting occurred, calculated for each RAD survey

5.3 Relative Abundance and Distribution of Narwhal

A total of 226 RAD surveys were completed over the course of 26 days between 6 August and 1 September 2019. A summary of the 2019 RAD data, compared to that collected from 2014 to 2017, is included in Table 5-1. Similar to previous years, narwhal were the most common species recorded at Bruce Head in 2019, followed by ringed seal and bearded seal. Less common species sightings recorded during 2019 included killer whale (multiple sightings), bowhead whale (n=1), beluga (n=2), and polar bear (n=2, observed on opposite shore). The total number of narwhal sightings (corrected for effort) in 2019 was shown to be comparable to that reported in previous survey years, including from baseline monitoring conducted in 2014, prior to the start of shipping operations in the RSA (Table 5-1; Golder 2019).

Over the five years of data collection, the number of RAD surveys completed per year ranged from 160 in 2017 to 321 in 2016 (Table 5-1). Where surveys were incomplete (e.g., at least one of the substrata had an impossible sightability or some of the substrata were not surveyed due to inclement weather), only the affected substrata were removed from analysis. That is, all substrata that were successfully surveyed, excluding those associated with impossible sightability, were included in the analysis. The average daily effort for RAD surveys ranged from 6.2 h in 2017 to 11.9 h in 2016. The lower number of RAD surveys in 2017 reflected a reduction in survey effort that year (one observation shift vs. two rotating observation shifts). Analysis of the RAD data excluded sightings made during 'impossible' sightability conditions and excluded an entire RAD survey conducted on 11 August 2017 in which counts were made in the same direction as a herding event and therefore had high potential of double-counting animals.

A total of 84,402 narwhal were observed in the SSA over the course of the five years of data collection (2014–2017 and 2019; Table 5-1). The annual counts ranged from 10,463 (2014) to 28,309 individuals (2016), reflecting both narwhal density and level of survey effort. When standardized by effort (i.e., RAD survey counts divided by length of survey [h]), the annual mean of survey-specific values of standardized narwhal counts ranged from 84.2 narwhal/h in 2015 to 156.4 narwhal/h in 2016 (Figure 5-8). Since mean values were strongly influenced by both zero counts and very high counts (as recorded in 2016; Figure 5-8), median values were also calculated. Median values of standardized counts ranged from 35.9 narwhal/h (in 2014) to 106.0 narwhal/h (in 2017).

Standardized daily counts of narwhal (narwhal/h) were bimodal in 2014, with a main peak (503 narwhal) on August 16 and a secondary peak (272 narwhal) on August 31 (Figure 5-8). In 2015, values of daily standardized counts were generally low (20 out of 29 survey days with values <70 narwhal/h). However, high values of daily standardized counts (>150 narwhal/h) were recorded on multiple days throughout the 2015 survey period (six days in August and one day in September). In 2016, daily standardized counts and their temporal distribution were similar to those recorded in 2014, with multiple high daily values (>150 narwhal/h) and two peaks in counts – in mid- and late-August. In 2017 and 2019, no counts with numbers greater than 400 narwhal/h were recorded. On average, daily counts values in 2017 and 2019 were between the relatively low values recorded in 2015 and the higher values recorded in 2014 and 2016.

In all years, multiple RAD surveys were conducted during which the total number of observed narwhal was zero (see Table 5-1). The proportion of zero-count RAD surveys varied from 41% of RAD surveys in 2014 to 52% in 2015, 41% in 2016, 22% in 2017, and 25% in 2019. This variation strongly affected the annual median values. The 2014-2016 median of daily standardized values ranged between 35.9 narwhal/h (in 2014) to 75.4 narwhal/h (in 2016) and increased to 106.0 narwhal/h in 2017 and 81.6 in 2019 (Figure 5-8).

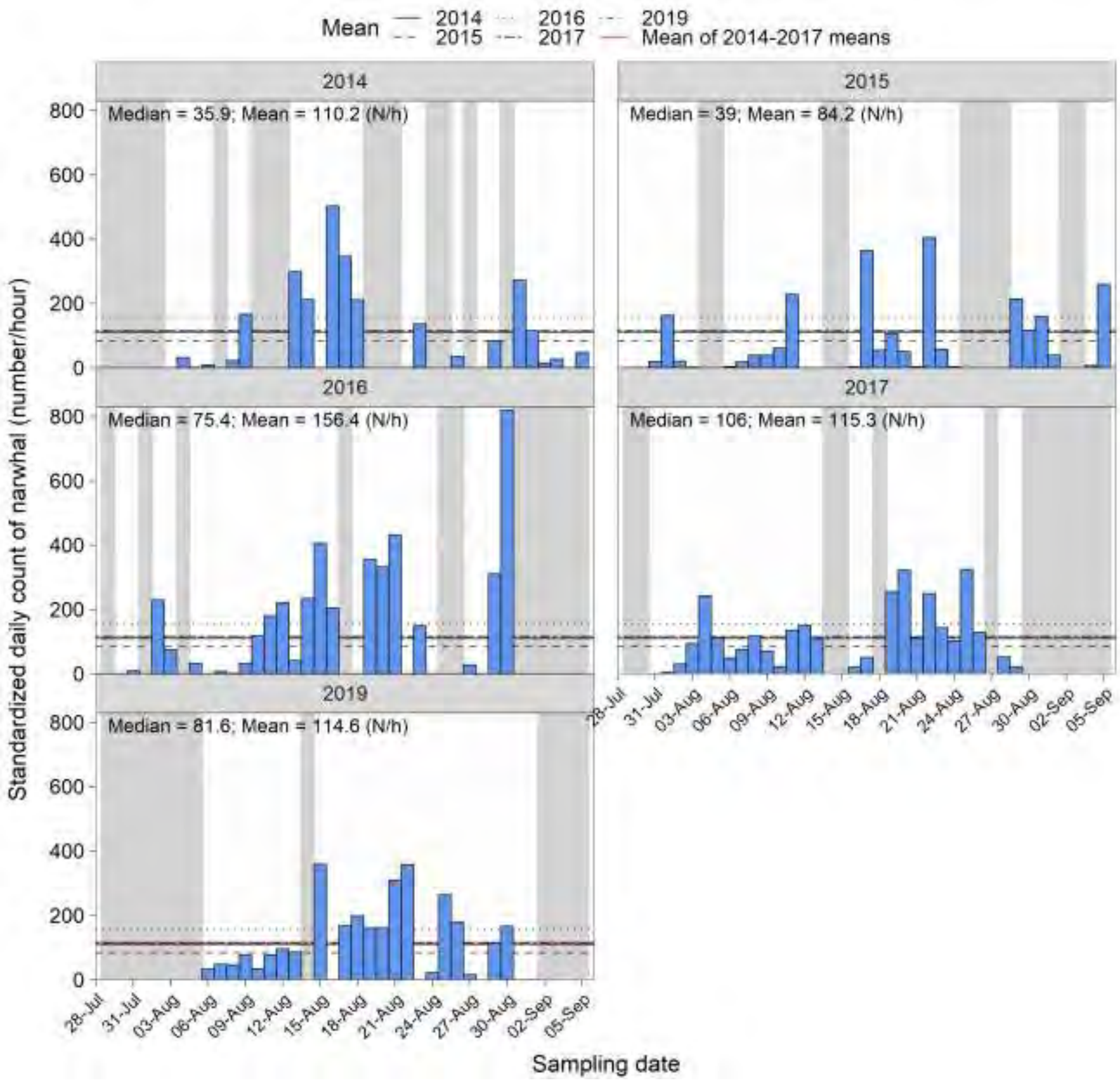


Figure 5-8: Standardized daily number of narwhal observed in the SSA from 2014–2019. Shaded area represents days that no data was collected

In general, stratum narwhal counts increased from north to south, as described in the 2014–2017 annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019). In each survey year, strata G, H, and I had the highest proportion of narwhal counts (Figure 5-9). Strata G, H, and I accounted for 62–72% of total counts in 2014–2017, and for 57% of total counts in 2019 (due to the introduction of stratum J, accounted for 23% of the total counts of narwhal). In comparison, strata A, B, and C only accounted for 5–11% of total annual counts in 2014-2019. Narwhal numbers also varied with substratum distance from the observation platform (Figure 5-9).

Each year, substratum ‘2’ had the highest percentage of total annual counts, accounting for 48–56% of total annual narwhal observations.

In addition to stratum and substratum, sightability also affected narwhal counts (Figure 5-9). Narwhal counts per RAD survey were considerably higher during periods when the sightability was considered ‘excellent’ and ‘good’, with ‘excellent’ sightability counts ranging between 21 narwhal/survey in 2014 and 63 narwhal/survey in 2016 (estimated 36 narwhal/survey in 2019) and ‘good’ sightability counts ranging from 22 narwhal/survey in 2015 to 42 narwhal/survey in 2016 (estimated 26 narwhal/survey in 2019). In comparison, ‘moderate’ sightability counts only ranged from 12 narwhal/survey in 2016 and 2019 to 23 narwhal/survey in 2017 (‘moderate’ sightability was not recorded before 2016) and ‘poor’ sightability counts ranged from 4 narwhal/survey in 2016 to 19 narwhal/survey in 2014 (before ‘moderate’ sightability was used and thus when ‘poor’ sightability also likely included some ‘moderate’ conditions).

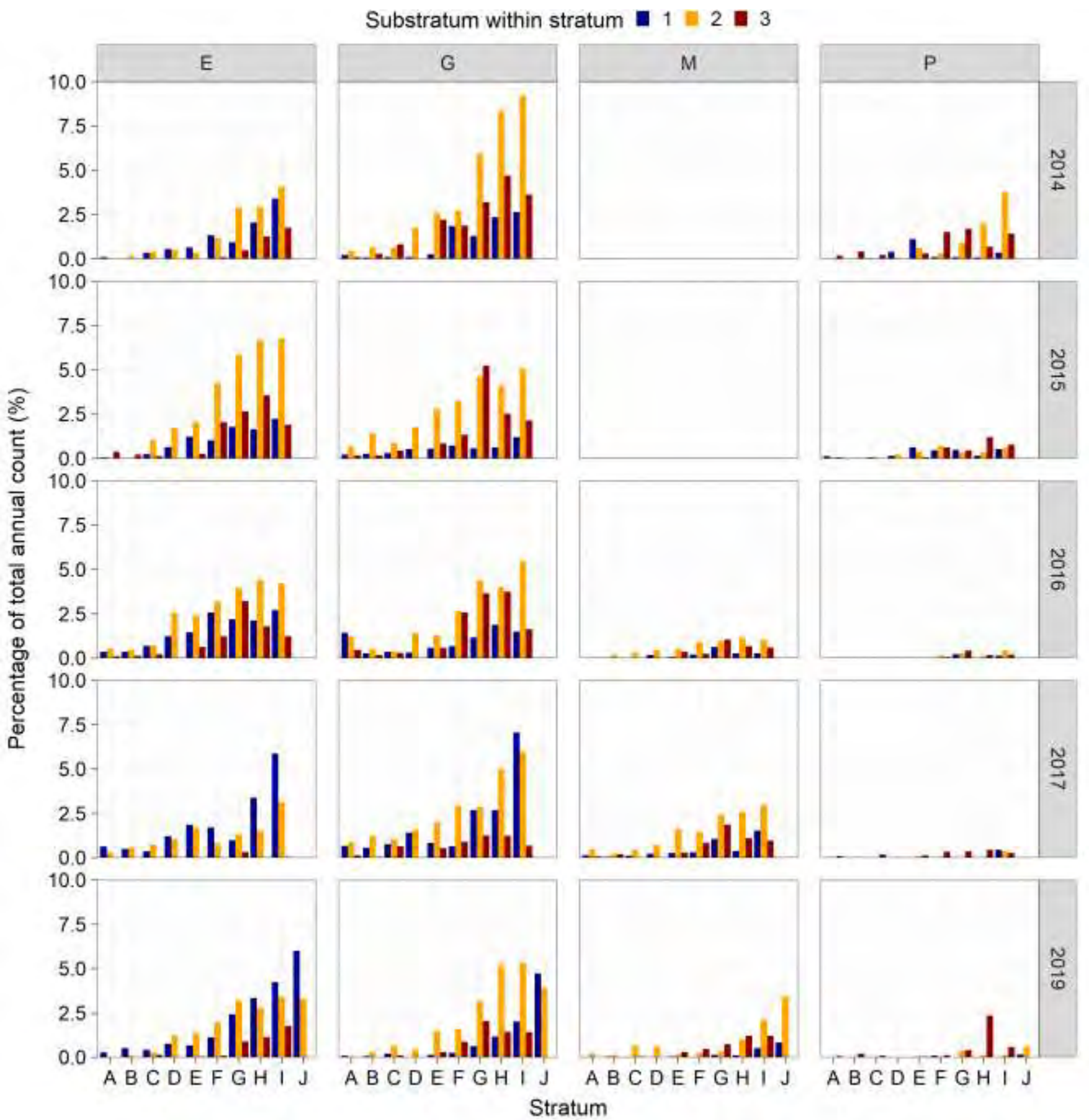


Figure 5-9: Percentage of narwhal counted in each substratum and sightability out of total narwhal counted in 2014-2017, 2019 (sightability categories were: E = excellent, G = good, M = moderate, P = poor)

In 2014–2017 and 2019, the proportion of narwhal observed in the presence of at least one vessel within 10 km of the substratum centroids increased from 3.1% in 2014 to 8.3% in 2015, 14.4% in 2016, 19.4% in 2017, and 17.7% in 2019. Of the narwhal counts recorded during periods when a single vessel was within 10 km, the majority of counts was recorded when vessels were northbound (98.8%, 70.5%, 88.1%, and 60.8% in 2014–2017, respectively), with the exception of 2019 in which 49.5% of counts were recorded when vessels were northbound.

In the combined 2014–2017 and 2019 RAD dataset, the majority of narwhal counts were recorded when no vessels were within 10 km of the SSA (n = 28,825 counts, 73,099 narwhal), at which time mean number of narwhal per substratum ranged from 1.8 individuals (in 2015) to 3.3 individuals (in 2016; Figure 5-10). In 2019, the mean number of narwhal per substratum when no vessels were within 10 km from substratum centroids was 2.6 individuals – higher than in 2014-2015, but lower than 2016 and 2017. When a single vessel was within 10 km of the SSA centroids, a total of 3,804 substrata were recorded over the years (with a total of 10,461 counted narwhal), at which time mean number of narwhal per substratum ranged from 1.6 individuals (in 2014) to 4.1 individuals (in 2016). In 2019, the mean number of narwhal per substratum when a single vessel was within 10 km of the SSA centroids was 2.2 individuals. When two or three vessels were within 10 km of the SSA centroids, a total of 127 substrata were recorded over the years (with a total of 842 counted narwhal), at which time mean number of narwhal per substratum ranged between 0 individuals (in 2014) and 21.2 individuals (in 2016). In 2019, the mean number of narwhal per substratum when multiple vessels were within 10 km of the SSA centroids was 0.5 individuals.

When vessels were present within 10 km of the SSA centroids, mean narwhal count per substratum varied in relation to 1) distance from the vessel transiting through the SSA and 2) direction of vessel. Throughout 2014-2017, mean narwhal counts were generally lower when southbound vessels passed through the SSA (2.5, 4.8, 5.7, and 4.0 individuals per substratum during a northbound transit in 2014-2017, respectively, compared with 0.05, 0.8, 1.3, and 3.1 individuals per substratum during a southbound transit in 2014-2017, respectively). In comparison, in 2019, mean values during northbound transits were slightly lower – 2.2 individuals per substratum, compared with 2.3 individuals per substratum during southbound transits (Figure 5-10).

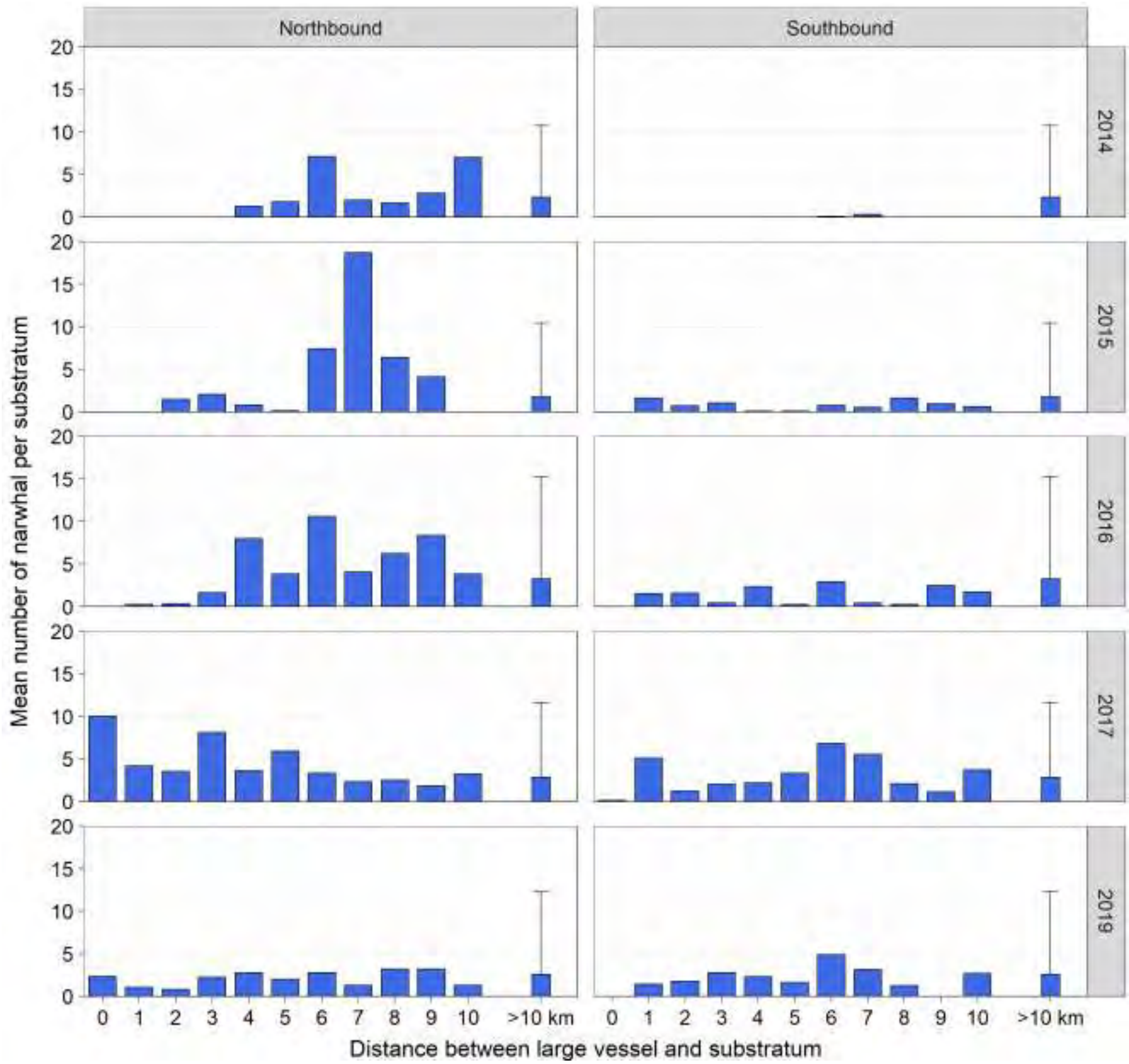


Figure 5-10: Mean narwhal counts in SSA relative to distance from vessel, binned to 1 km (2014–2019)

Notes: Observed data depict annual mean for each x-axis value and mean and standard deviations for >10 km cases (all other variables are not held constant).

The relationship between narwhal counts within strata and tidal conditions was not consistent between years (Figure 5-11). Within each stratum, counts were generally higher during ebb tides than during flood tides in 2014, 2015, and 2016, but not in 2019. Due to the inconsistency in the relationship, the tide conditions were not included in the models as a predictor variable.

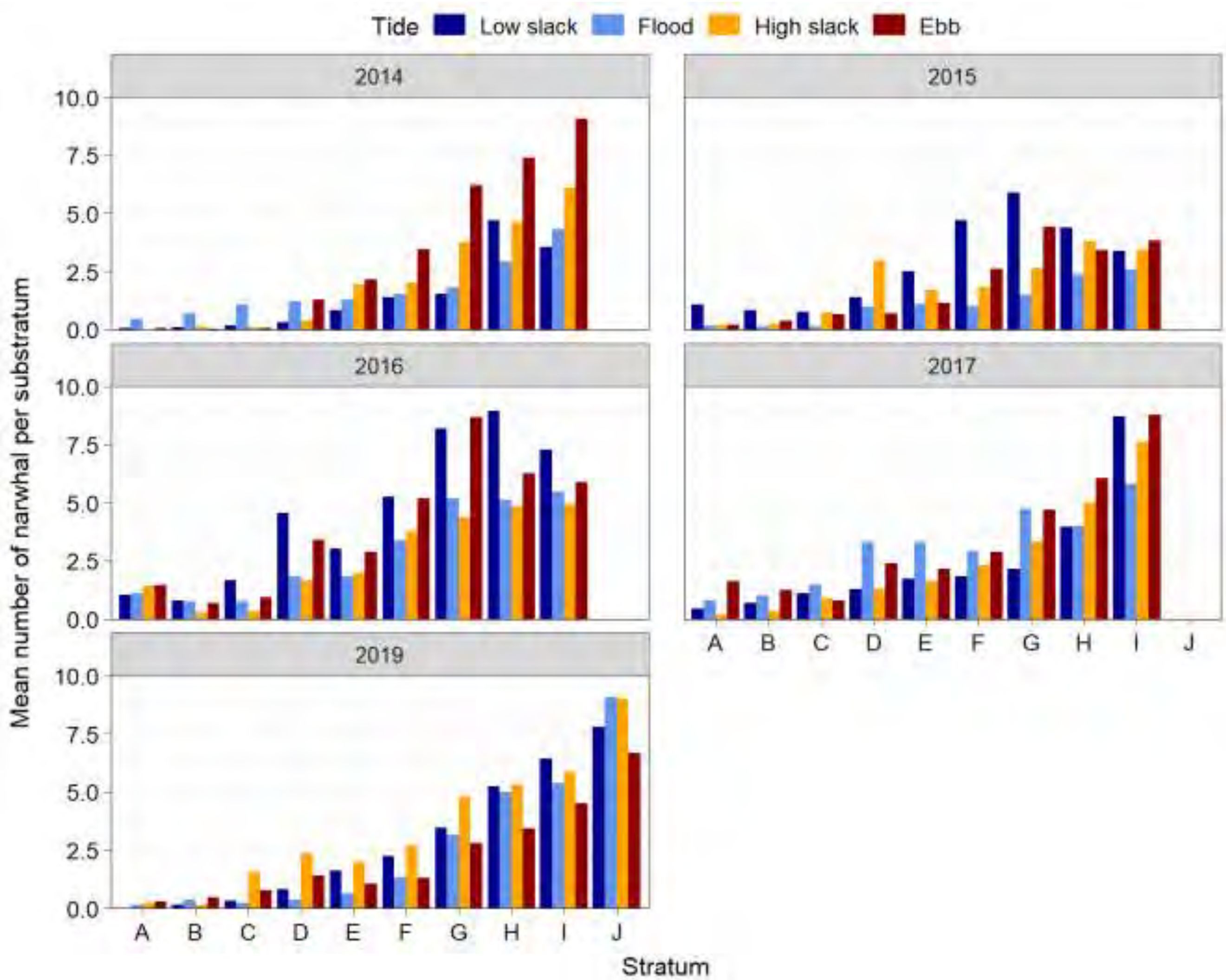


Figure 5-11: Mean narwhal counts in SSA relative to tide stage, stratum, and year (2014–2019)

The majority of data (88%) was collected when no vessels were within 10 km from substratum centroid (Figure 5-12). A total of 12% of the data was collected when a single vessel was within 10 km from substratum centroid (3,767 cases), and <1% of the data was collected when two or three vessels were within 10 km from substratum centroid (105 cases and 8 cases, respectively). Mean number of narwhal increased from 2.6 individuals/substratum when no vessels were present to 2.8 individuals/substratum when a single vessel was present, and 7.5 individuals/substratum and 6.8 individuals/substratum when two or three vessels were present within 10 km, respectively.

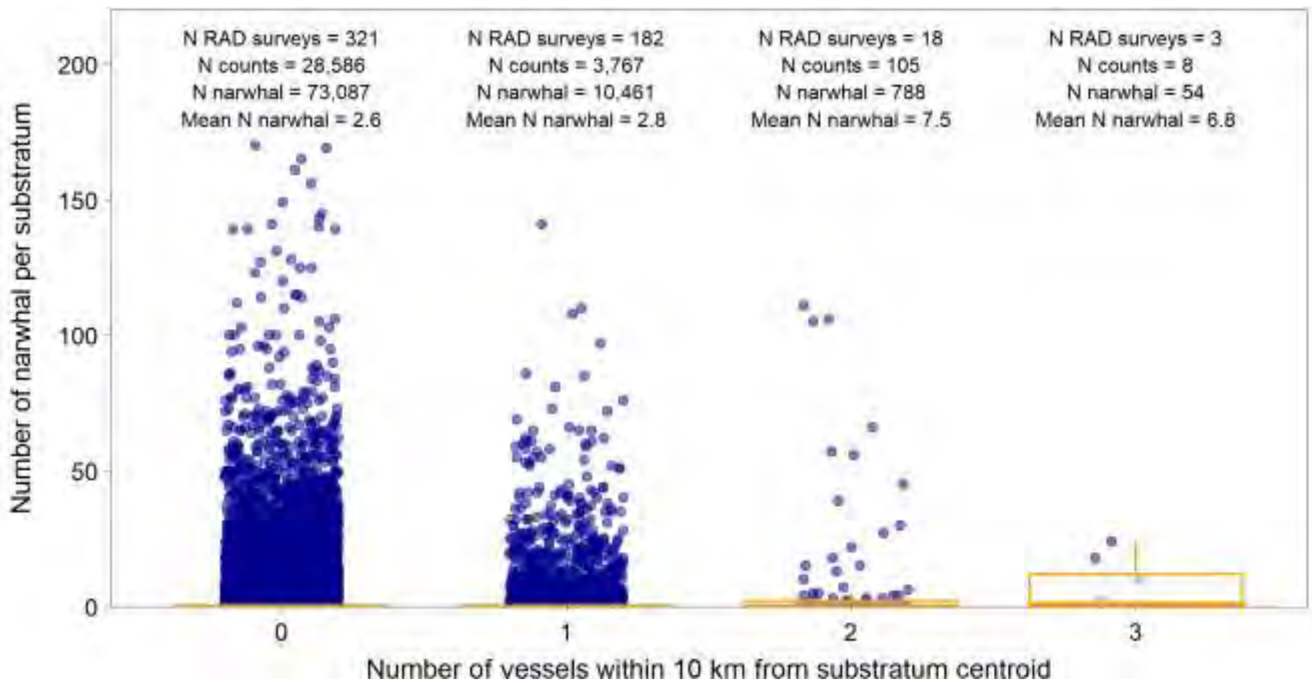


Figure 5-12: Narwhal observations versus the number of vessels within 10 km from substratum centroid. Three cases of narwhal counts ≥200 individuals are not shown (all three had no vessels within 10 km).

5.3.1 RAD Modeling

Of the compiled 32,756 substratum counts (excluding "impossible" sightability), a total of 3,804 (11.6%) had a single vessel present within 10 km from the relevant substratum centroid. A total of 127 cases (0.4%) had two or more vessels within 10 km from the relevant substratum centroid.

Based on the smoothing trend curve (i.e., not accounting for any other pertinent variables), an increase in narwhal counts was observed in 2014-2016 when a northbound vessel was approximately 5-8 km from a centroid, whether the vessel was moving toward the substratum or moving away from it (Figure 5-13). In the presence of southbound vessels, this effect was seen mostly when vessels were moving toward the substratum, but less so when the vessel was moving away from the substratum. Overall, the data suggest a difference in narwhal counts in the presence of north- and southbound vessels, as well as differences in narwhal counts in the presence of vessels moving toward substrata or moving away from substrata, especially for vessels transiting southbound.

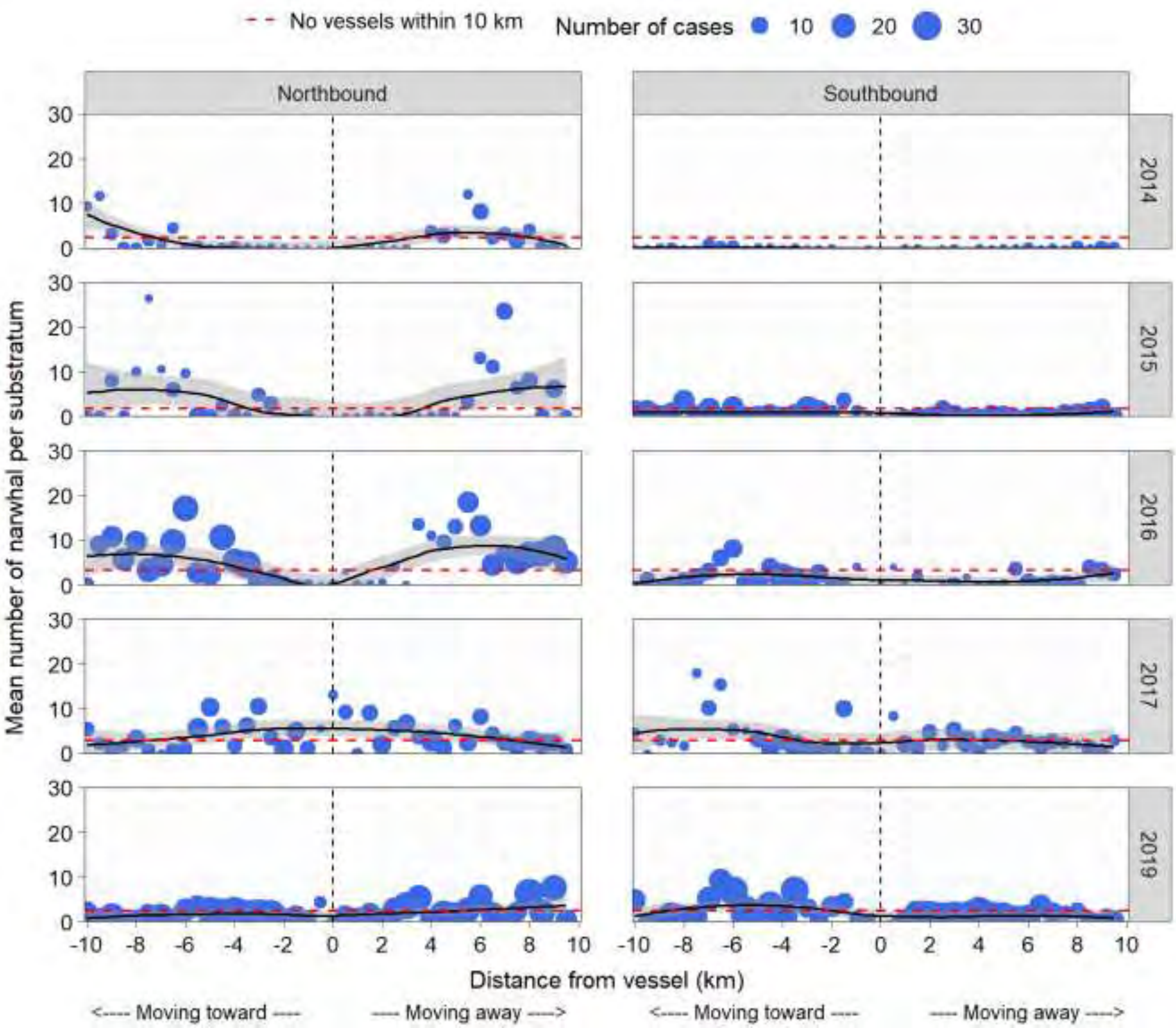


Figure 5-13: Mean number of narwhal per substratum, by distance from vessels (rounded to 1 km), direction of vessel within Milne Inlet, and by sampling year. Bubble size represents total amount of data available for each distance, direction, and year combination. Horizontal lines depict mean narwhal counts per substratum when no vessels were present within 10 km from substratum centroids. Curve and confidence band represent a LOESS (locally estimated scatterplot smoothing) trend curve.

The model of relative abundance data had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.243. That is, the model's fixed effects explained approximately 24% of the variability in observing south-travelling groups. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

The full model of RAD counts had a zero-inflation component that depended on stratum, substratum, and Beaufort scale. The full model was preferred over a model with an intercept-only zero-inflation ($P<0.001$) and over a negative binomial model with no zero inflation ($P<0.001$). This indicates that these three fixed effect predictors affect not only narwhal counts, but also the probability of recording narwhal presence – whether due to sighting conditions (Beaufort scale effect and distance of the substratum), or spatial (stratum) distribution within the SSA. All three effects were significant (*P*<0.001) predictors in the zero-inflation component of the full mixed model (Appendix C, Table C-1).

In the model of relative abundance, the effects of day of year, stratum, substratum, glare, Beaufort scale, tide, time since the last shooting event, and whether hunting has occurred in the 3 h preceding the observation were statistically significant (*P*<0.001 for all; Appendix C, Table C-1). The effects of year and presence/absence of small vessels within the SSA were not statistically significant (*P*=0.2 and *P*=0.3, respectively). The three-way interaction between distance, vessel direction relative to substratum, and vessel direction within Milne Inlet was significant (P=0.024). The model had sufficient power (>0.8) to detect a -35% or a +45% effect size in the test of the overall effect of distance from vessel, and sufficient power (>0.8) to detect a -70% or a +100% effect size in the test of effect of number of vessels present within 10 km from the substratum (Appendix E).

Mean narwhal counts were estimated to increase throughout the strata, from the lowest estimate at stratum A to the highest estimate in strata I and J, as well as throughout the substrata, with the lowest estimate at substratum ‘3’ and the highest at substratum ‘2’ (Figure 5-14, panel A). For example, at the predictor levels used for visualization of model results (year = 2017, date = 15 August, Beaufort value of 2, glare = ‘none’, no vessels present within 10 km, no small vessels within the SSA, and no hunting activity), narwhal predictions increased from 0.51 narwhal/count in substratum A2 to 5.7 narwhal/count in substratum I2. Similarly, for the same predictor values and for stratum F, narwhal count predictions increased from 1.0 narwhal/count in substratum ‘3’ to 1.4 narwhal/count in substratum ‘1’, and to 2.3 narwhal/count in substratum ‘2’.

Mean counts were estimated to decrease from 3.2 narwhal/count and 3.4 narwhal/count at Beaufort values of 0 and 1, respectively, to 2.3 narwhal/count and 1.4 narwhal/count at Beaufort levels of 2 and 3, respectively, and to 1.1 narwhal/count and 0.8 narwhal/count at Beaufort levels of 4 and 5, respectively. Multiple comparisons between levels of the Beaufort scale indicated that counts made at Beaufort levels of 0 and 1 were not statistically different, whereas each following increase in Beaufort values led to a significant decrease in observed counts (Figure 5-14). These results indicate that Beaufort values above 1 significantly affect the observers’ ability to count narwhal, and that observations made at Beaufort values of 3 and higher could be strongly underestimating the true counts of narwhal. Mean counts estimated under no glare, low glare, and severe glare were estimated to all be significantly different from each other, with counts under severe glare estimated to be the lowest (1.5 narwhal/count) and counts under low glare estimated to be the highest (2.3 narwhal/count; Figure 5-14).

Multiple comparisons between predictions at different tide levels suggested that mean estimates were significantly different between high slack (2.2 narwhal/count), ebb (2.5 narwhal/count), and low slack (3.0 narwhal/count) conditions, but not between high slack and flood conditions, or between flood and ebb conditions (Figure 5-14). This differs from previous findings, where counts were reported to be highest during ebb conditions, and the remaining three conditions were not found to be significantly different from each other (Smith et al. 2017).

The effect of day of year (presented as date in Figure 5-14) was dome-shaped, with lower counts observed and predicted in the early and late season (mean predicted values of 0.1 narwhal per observation on 29 July and 0.7 narwhal per observation on 05 September of 2017), and higher mid-season (mean predicted value of 2.7 narwhal on 21 August 2017).

The estimated narwhal counts immediately following hunting were higher (e.g., 3.9 narwhal/count at 0 min post shooting) than when no hunting occurred within the 3 h preceding the survey (2.3 narwhal/count; Figure 5-15). The higher counts immediately following hunting were likely the cause, rather than the effect, of hunting.

Statistical comparisons of mean predicted counts at 10 min increments following a shooting event to the mean counts when no hunting occurred within the preceding 3 h found significant differences for times up to 50 min post shooting ($P<0.009$ for all comparisons), whereas a comparison with 60 min post shooting was not significant ($P=0.15$).

Population-level estimates of narwhal counts generally showed an increase in mean estimates when northbound vessels were approximately 6-8 km from the SSA (2.6-3.4 narwhal/count) relative to when no vessels were within 10 km (2.3 narwhal/count), regardless of vessel direction relative to the SSA (Figure 5-15). When northbound vessels were within 2 km from the SSA, mean estimates were lower (1.2-1.8 narwhal/count) relative to when no vessels were within 10 km. When southbound vessels were moving toward the SSA, mean estimates were highest (1.7-2.2 narwhal/count) when the vessel was 1-4 km from the substratum, and decreased to 1.1 narwhal/count as the vessel approached to 0 km of the substratum. When southbound vessels were moving away from the SSA, mean estimates were high (4.2 narwhal/count) when the vessel was at 0 km from the substratum, then declined to 1.7 narwhal/count when the vessel was 2 km from the substratum, and increased to 2.9 narwhal/count when the vessel was at 7 km from the substratum. However, note that in the case of southbound vessels moving away from the substratum, the model strongly overestimated the observed counts at close proximity (0-1 km), due to the inability to capture trends at a small spatial extent given the overall 10 km spatial extent.

As a result of the high uncertainty, few of the multiple comparisons between narwhal counts when vessels were at 0-10 km and narwhal counts when no vessels were present were statistically significant (Table 5-3). Of those, the results that were significant when vessels were in closer proximity (<3 km) and where the effect was expected to be strongest, were for northbound vessels heading away from substratum. These results indicated a possible, though uncertain relationship between relative abundance of narwhal and distance from vessel. The model found even fewer significant differences when performing multiple comparisons between narwhal counts when 2+ vessels were within 10 km from the relevant substratum and when and no vessels were present (note that distance, direction, and relative position refer to the nearest vessel, not all vessels; Table 5-4). Specifically, only when 2+ vessels were present within 10 km from the relevant substratum, and the nearest vessel was northbound and headed toward the substratum, were narwhal counts found to be significant different from when no vessels were present within 10 km. A pairwise comparison between the presence of a single vessel at 0 km and presence of 2+ vessels within 10 km from substratum, where the nearest vessel was also at 0 km was not significant ($P=0.18$).

In summary, the overall relative abundance of narwhal in the SSA, inferred from sighting rate (no. of narwhal per hour - corrected for effort), has remained relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. However, within each study year, a likely but uncertain effect of vessel exposure on narwhal relative abundance in the study area (SSA) was observed. Specifically, vessel exposure was shown to result in a significant decrease in narwhal sightings in the SSA compared to when no vessels were present, but only when narwhal were exposed to vessels travelling north and away from the study area, and only at close exposure distances of 2-3 km. These results suggest that the relative abundance of narwhal was influenced by vessel traffic at close distances, although the exact spatial extent of this effect could not be determined due to high data variability. The results support rejection of the null hypothesis that relative abundance of narwhal does not significantly change during vessel-exposure events.

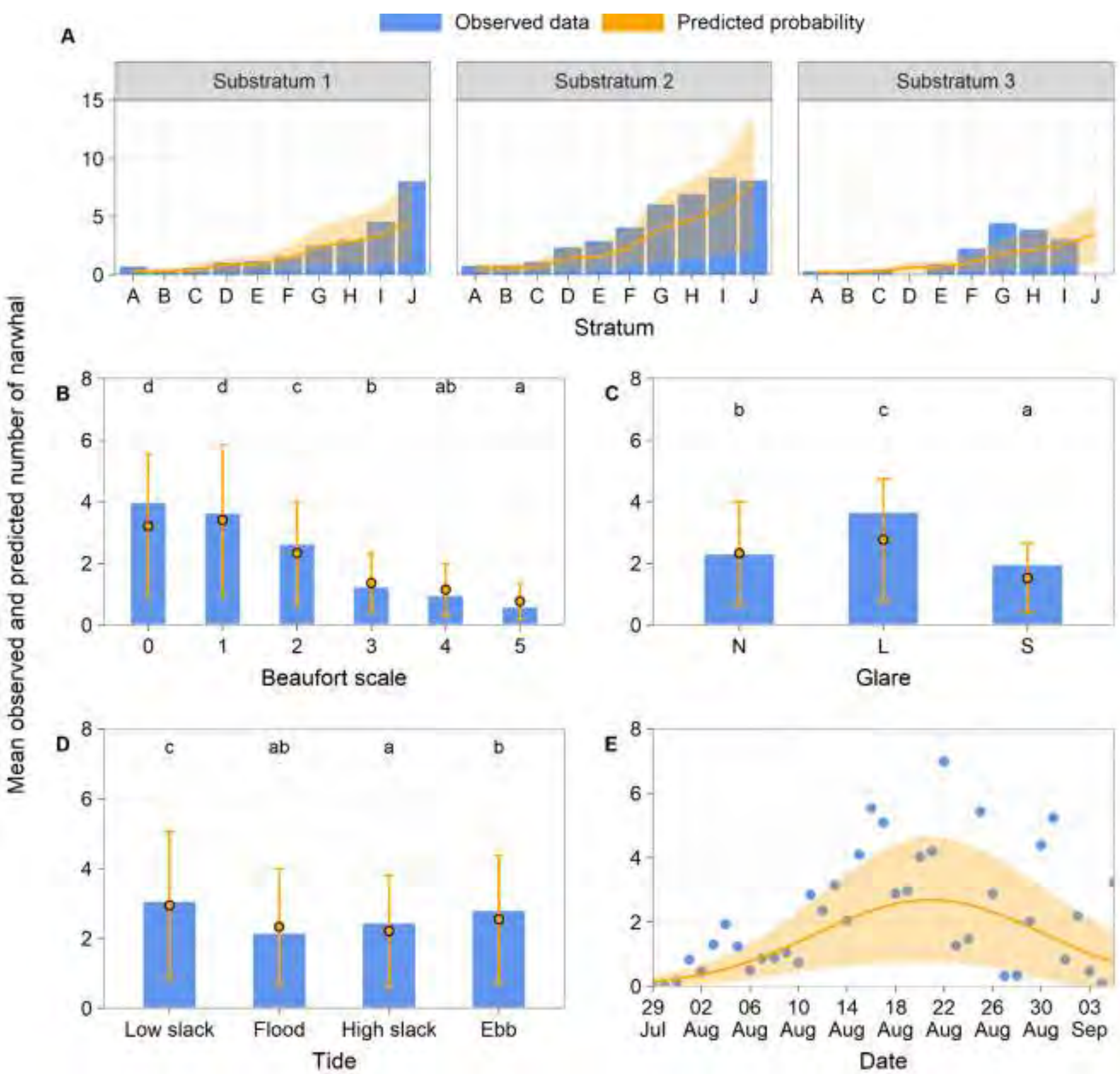


Figure 5-14: Mean observed and predicted narwhal counts relative to stratum and substratum (panel A), Beaufort scale (panel B), glare (panel C), tide (panel D), and date (panel E).

Notes: observed data depict mean substratum-level count of narwhal at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B, C, and D), different letters indicate significant difference between groups.

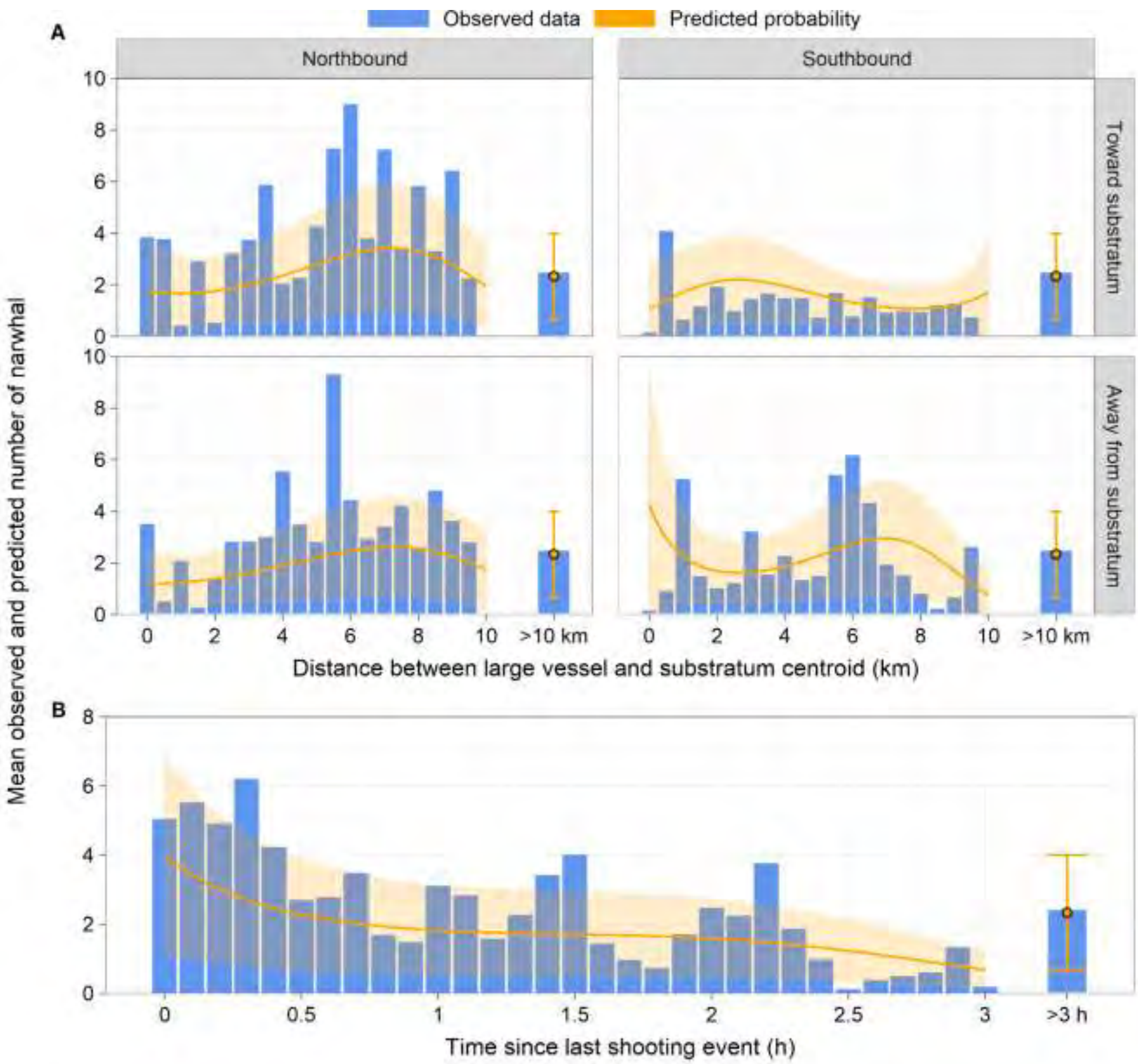


Figure 5-15: Mean observed and predicted narwhal counts relative to distance from vessels in transit, vessel direction in Milne Inlet, and direction relative to the SSA centroids (2014–2019; panel A), and hunting activity (panel B).

Notes: observed data depict mean substratum-level count of narwhal at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

Table 5-3: Multiple comparisons of predictions of narwhal counts when no vessels are within 10 km from the substratum and predictions at specific distances between substratum and vessels; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward substratum	Northbound vessel, away from substratum	Southbound vessel, toward substratum	Southbound vessel, away from substratum
0	1.7 (0.988)	1.2 (0.669)	1.1 (0.863)	4.2 (0.788)
1	1.7 (0.766)	1.2 (0.071)	1.7 (0.920)	2.3 (1.000)
2	1.8 (0.380)	**1.4 (0.002)**	2.1 (0.989)	1.7 (0.237)
3	2.0 (0.798)	**1.6 (0.029)**	2.2 (0.996)	1.6 (0.137)
4	2.4 (1.000)	1.9 (0.388)	1.9 (0.808)	1.9 (0.520)
5	2.8 (0.414)	2.2 (0.980)	1.6 (0.073)	2.3 (1.000)
6	**3.2 (0.003)**	2.5 (0.988)	**1.3 (0.002)**	2.7 (0.782)
7	**3.4 (<0.001)**	2.6 (0.890)	**1.1 (0.001)**	2.9 (0.513)
8	**3.3 (0.001)**	2.5 (0.958)	**1.1 (<0.001)**	2.6 (0.970)
9	2.8 (0.557)	2.2 (0.999)	**1.2 (0.027)**	1.7 (0.736)
10	2.0 (0.955)	1.7 (0.904)	1.7 (0.971)	0.8 (0.193)

Table 5-4: Multiple comparisons of predictions of narwhal counts when no vessels are within 10 km from the substratum and predictions of 2+ vessels at specific distances between substratum and the nearest vessel; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward substratum	Northbound vessel, away from substratum	Southbound vessel, toward substratum	Southbound vessel, away from substratum
0	2.2 (1.000)	1.5 (0.932)	1.3 (0.966)	5.4 (0.514)
1	2.1 (0.999)	1.6 (0.731)	2.2 (1.000)	2.9 (0.959)
2	2.2 (1.000)	1.8 (0.776)	2.7 (0.980)	2.2 (0.997)
3	2.5 (0.996)	2.1 (0.982)	2.8 (0.960)	2.1 (0.990)
4	3.0 (0.771)	2.4 (1.000)	2.5 (0.999)	2.4 (1.000)
5	3.6 (0.219)	2.8 (0.911)	2.1 (0.987)	2.9 (0.869)
6	**4.1 (0.034)**	3.1 (0.597)	1.7 (0.688)	3.5 (0.368)
7	**4.4 (0.015)**	3.3 (0.450)	1.4 (0.365)	3.8 (0.227)
8	**4.2 (0.032)**	3.2 (0.561)	1.4 (0.267)	3.3 (0.606)
9	3.5 (0.338)	2.9 (0.937)	1.5 (0.622)	2.2 (0.999)
10	2.5 (1.000)	2.2 (1.000)	2.2 (1.000)	1.0 (0.517)

5.3.2 UAV Data

Technical issues and inclement weather limited the successful collection of UAV data in 2019 to August 29, during which strata H and I were surveyed under adequate observation conditions. Photo examples collected during this survey are presented in Figure 5-16. Narwhal counts conducted during the UAV survey, in comparison to the concurrent visual surveys, are shown in Table 5-5. In general, narwhal were observed travelling through the SSA during these surveys, particularly in substratum 1 and 2, which made comparing visual sightings observations with UAV observations challenging due to the extended duration required to survey a given substrata via the UAV compared to the visual observer. The single successful UAV survey of narwhal included a large herding event that took place during the assessment of stratum I. During this survey, Inuit hunting activities at Bruce Head (gunshots and small vessel movement) were also observed during the assessment of I1 and I2. Although this limited dataset is not suitable to adequately assess observer bias, lessons learned from the 2019 Program will be applied to future UAV monitoring efforts.

Figure 5-16: Example UAV narwhal photos (clipped areas): adult narwhal travelling through substratum I1 during herding/hunting event at left, and three adult narwhal and one calf in substratum H2 at right.

Table 5-5: Comparison of UAV and visual survey results

Sub-stratum	Start time	Visual Observer				Photographic Survey	
		Duration (minutes)	Sea State	Glare	# Narwhal	Duration (minutes)	# Narwhal
H1	11:35	1	1	none	6	3	26
H2	11:26	2	2	none	0	8	82
H3	12:12	1	1	light	0	9	0
I1	14:06	1	1	none	73	8	346
I2	13:52	1	1	none	20	12	108
I3	13:19	1	1	none	0	11	3

5.4 Group Composition and Behaviour of Narwhal

The total number of sampling days in which data on narwhal group composition and behaviour were collected within the BSA ranged from 11 days in 2014 to 27 days in 2017; in 2019, data within the BSA were collected on 24 days (Table 5-6). The number of narwhal groups observed during these days ranged from 250 groups (totaling 1,086 narwhal) in 2014 to 2,416 groups (totaling 8,913 narwhal) in 2017; in 2019, 1,370 groups were observed, totaling 5,231 narwhal (Table 5-6). A total of 31 groups were recorded under ‘impossible’ sightability conditions (8 and 23 groups in 2016 and 2017, respectively) and were excluded from further analyses. The proportion of narwhal groups recorded in the BSA during periods of ‘no anthropogenic activity[6]’ decreased from 91% in 2014 to 36% in 2019 (58% in 2015, 62% in 2016, 49% in 2017), consistent with the increase in vessel traffic over time.

Table 5-6: Number of narwhal recorded in BSA during group composition / behaviour surveys (2014–2017 and 2019)

Survey Year	# Sampling Days	# Narwhal Groups	# Narwhal
2014	11	250	1,086
2015	17	287	1,568
2016	26	702	2,171
2017	27	2,416	8,913
2019	24	1,370	5,231

Note: data collected under ‘impossible’ sightability conditions were omitted from this table and the multi-year analysis.

In the combined 2014–2017 and 2019 dataset, when “impossible” sightability data was removed, most narwhal sightings in the BSA occurred when no vessels were present within 10 km of the BSA (n = 4,341 cases). A total of 644 sightings and 40 sightings occurred when a single vessel or two or more vessels were present within 10 km

[6] large and small vessel transits, active shooting events

of the BSA (12.8% and 0.8%, respectively). Annually, the percentage of sightings that occurred when no vessels were present within the BSA ranged from 76% (in 2015) to 100% (in 2014). In 2019, 87% of the sightings occurred when no vessels were present. The percentage of observations when a single vessel was present within 10 from the BSA ranged from 5% (in 2016) to 24% (in 2015). In 2019, 13% of the sightings were recorded when a single vessel was within 10 km from the BSA. The percentage of observations when two or more vessels were present within 10 km from the BSA ranged from was 0% in 2014 and 2015, 5% in 2016, 0.1% in 2017, and 0.2% in 2019.

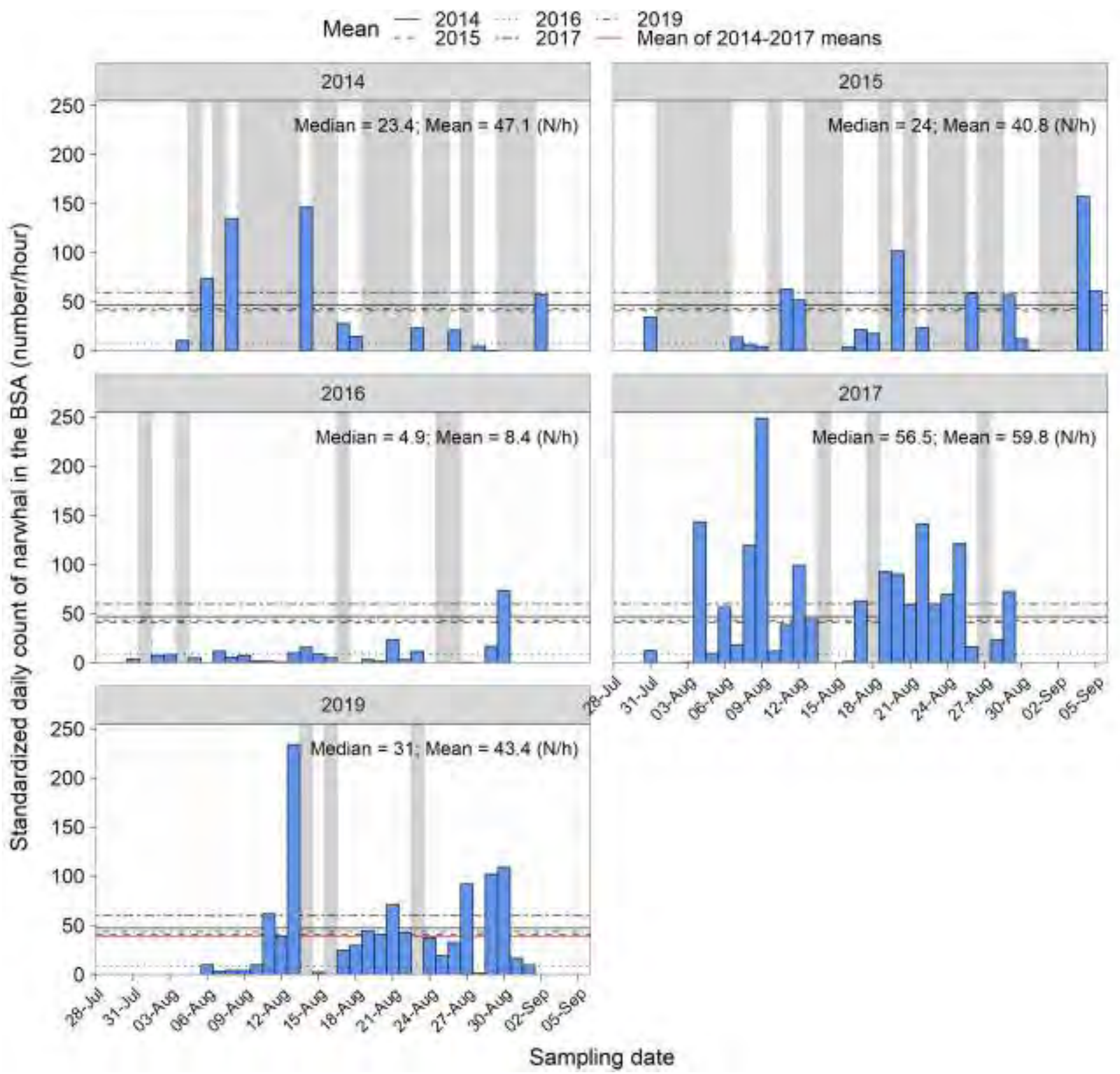


Figure 5-17: Standardized daily number of narwhal observed per hour of observation in the BSA (2014–2017 and 2019). Shaded area represents days that no data was collected.

The majority of narwhal groups in the BSA were recorded during 'excellent' sightability conditions in all sampling years except for 2016, and during 'good' sightability conditions in 2016 (Figure 5-18). The proportion of narwhal groups recorded during 'poor' sightability conditions was relatively high in 2015 (21%). This was an artefact of the 'moderate' sightability category not being used during the first two years of the program, therefore inflating the number of sightings assigned to 'poor' by default. In 2019, the proportions of narwhal recorded within the BSA under the various sightability levels were overall similar to those recorded in 2017 (Figure 5-18).

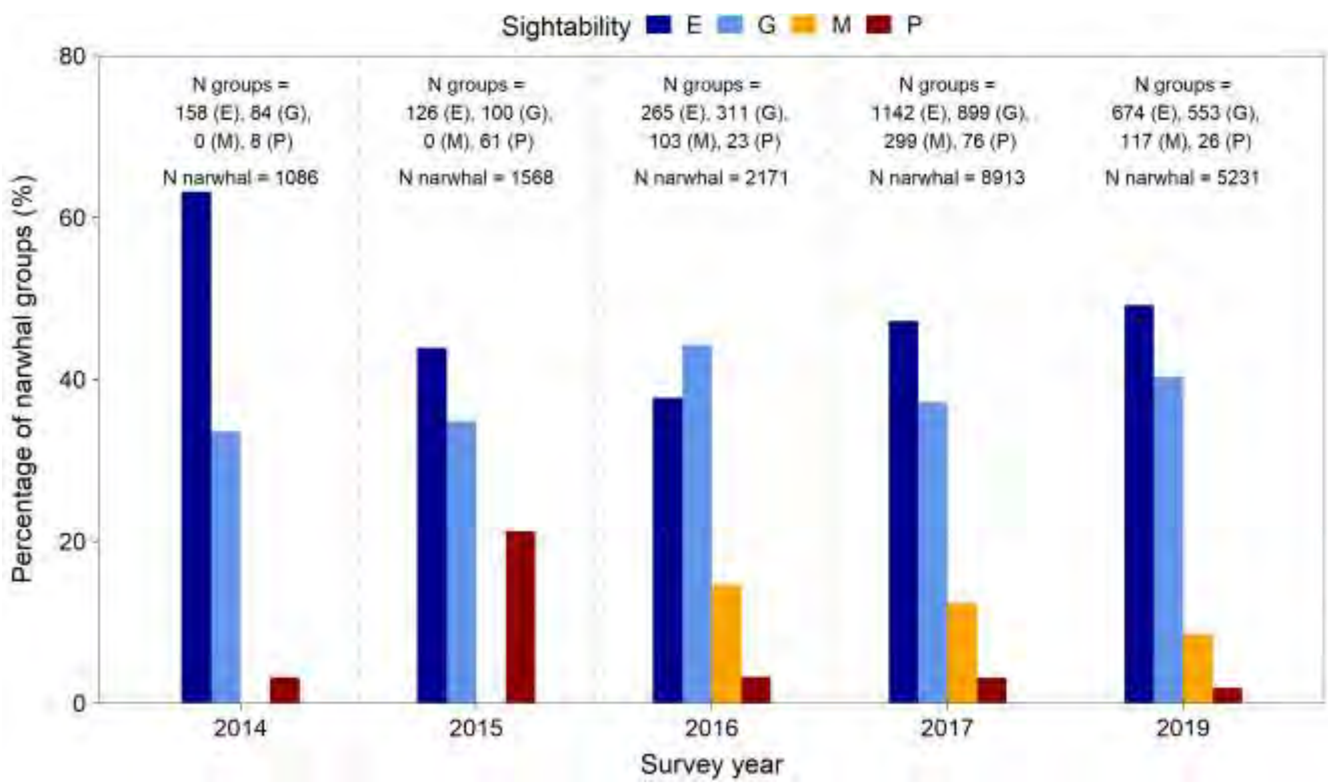


Figure 5-18: Percentage of narwhal groups in the BSA by sightability conditions, 2014-2017, 2019

Note: Annual group counts and total number of narwhals observed by sightability are provided for each year.

5.4.1 Group Size

Throughout the five years of data collection, the number of narwhal observed per group was relatively small, generally between one and five individuals (Figure 5-19). Groups larger than 25 individuals were only recorded once in 2014, three times in 2015 (with group sizes up to 45 individuals), and five times in 2019 (with group sizes up to 35 individuals). Mean group size in the BSA was 4.3 in 2014, 5.5 in 2015, 3.1 in 2016, 3.7 in 2017, and 3.8 in 2019.

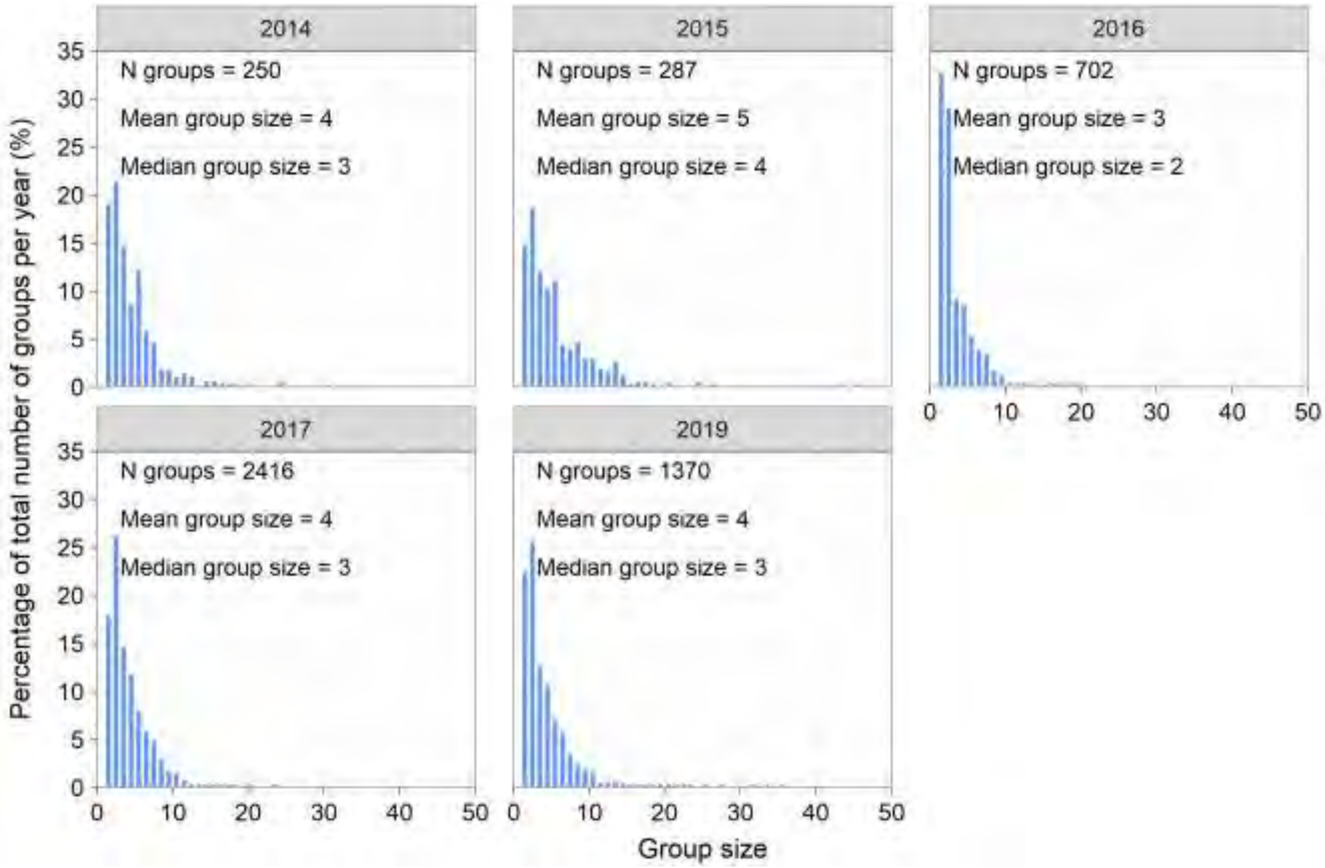


Figure 5-19: Distribution of group size observed in BSA (2014–2017, 2019)

Mean group size when no vessels were present was 3.7 individuals (SD = 2.9 individuals; Figure 5-20). When vessels were present within 10 km of the BSA, a total of 683 narwhal groups were sighted with mean group size of 3.9 individuals (SD = 3.2 individuals). Of the 683 observations when vessels were present, 150 and 208 groups were recorded when a vessel was northbound and heading toward or away from the BSA, respectively, and 164 and 161 cases were recorded when a vessel was southbound and heading toward or away from the BSA, respectively. Mean group size of narwhal observed under these four vessel passage scenarios ranged from 2.2 (northbound vessel heading toward the BSA) to 4.1 (southbound vessel heading toward the BSA).

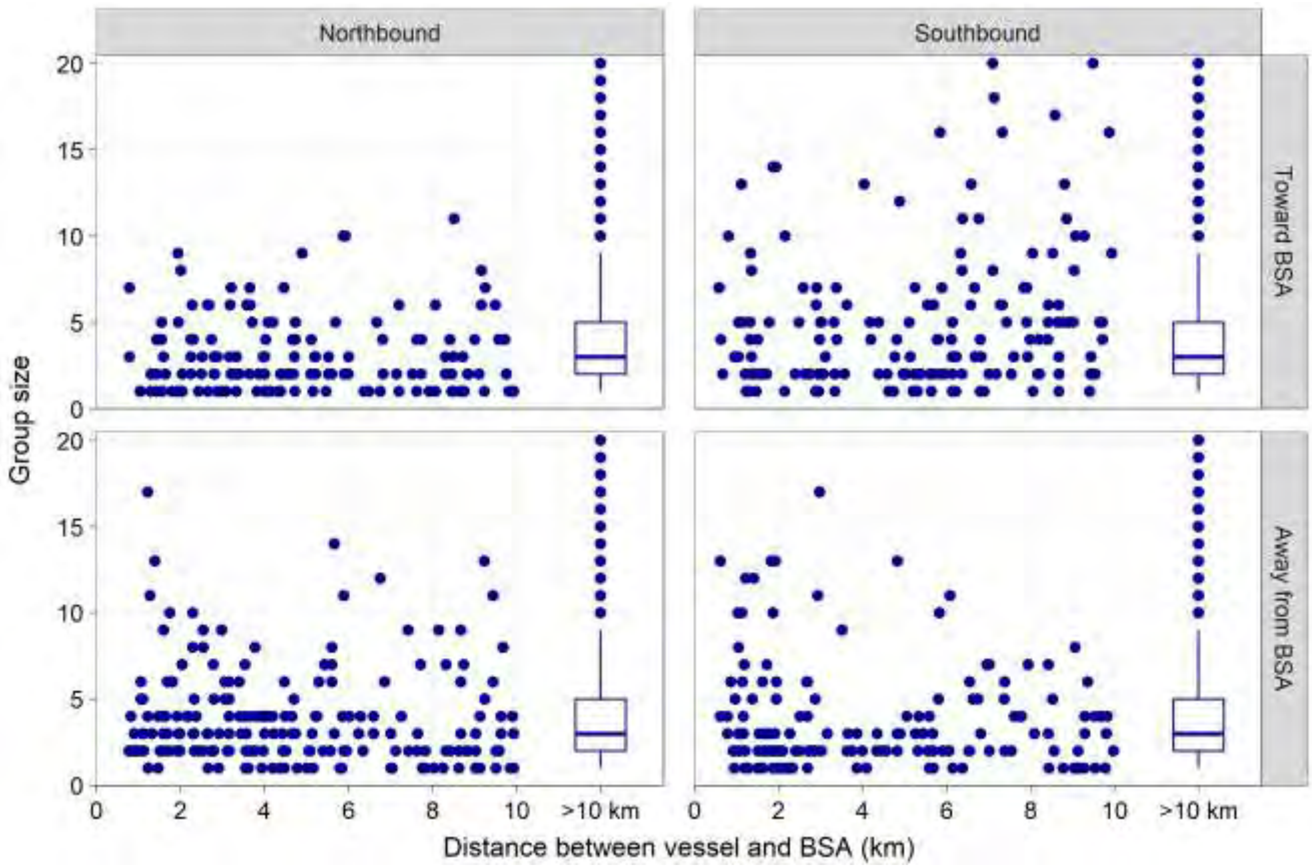


Figure 5-20: Group size of narwhal groups observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019).

The model of narwhal group size had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.215. That is, fixed predictor variables in the model explained approximately 22% of the variability in group size. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

The effects of survey year, glare, and hunting activity were statistically significant in the model of group size (all $P \leq 0.006$; Appendix C, Table C-3). Multiple comparisons of survey years indicated that 2016 and 2019, when group sizes were on average smaller, were significantly different from 2015, when group sizes were on average the largest (Figure 5-21). Multiple comparisons of glare effects indicated that there was no significant difference in group size between "no glare" and "low glare" scenarios, however group sizes were significantly larger during "severe glare" than during "no glare" or "low glare" (Figure 5-21). The effects of shipping (distance from vessel, vessel direction within Milne Inlet or vessel direction relative to the BSA) were not statistically significant ($P>0.2$ for all effects). The model had sufficient power (>0.8) to detect a -35% or a +45% effect size in the test of the overall effect of distance from vessel, and sufficient power (>0.8) to detect a -55% or a +92% effect size in the test of effect of number of vessels present within 10 km from the BSA (Appendix E).

The population-level estimates (i.e., predictions of group size on a typical day) of narwhal group size immediately following hunting were larger (e.g., mean of 2.8 individuals 0 min post shooting) than when no hunting occurred within the 3 h preceding the survey (mean of 2.0 individuals). No abrupt change in group size was evident immediately after hunting, suggesting that the larger group sizes during hunting activity are the cause of hunting, rather than the effect of shots fired. Statistical comparisons of group sizes at 10 min increments following a shooting event to group size when no hunting occurred within the preceding 3 h indicated that group sizes were significantly different after hunting up to 70 min following a shooting event ($P<0.05$ for all, ranging from $P<0.001$ immediately after a shooting event, to $P=0.028$ 70 min after a shooting event). Starting at 80 min after a shooting event, group sizes were no longer significantly different from when no hunting occurred ($P>0.1$ for all).

In summary, the 2014–2017 and 2019 integrated Bruce Head data do not support rejection of the null hypothesis that group size does not significantly change during vessel-exposure events. That is, findings did not suggest that narwhal alter their group size as a potential anti-predator response to vessel traffic. However, the model only had sufficient power to detect an effect size of -35% or +45% relative to when no vessels were present, whereas observed effect sizes only ranged between -11% and +27%.

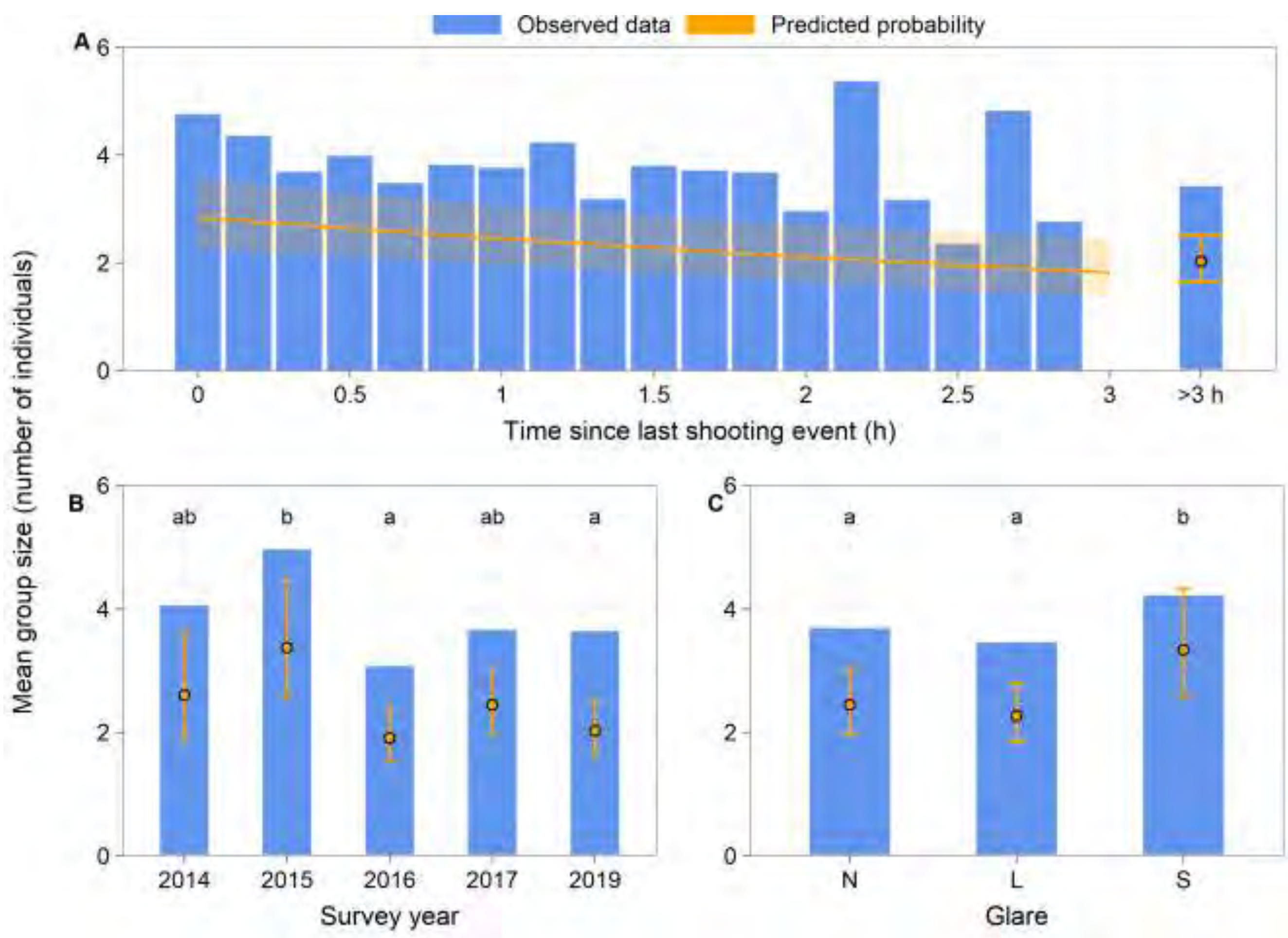


Figure 5-21: Mean narwhal group size relative to hunting activity in the BSA (2014–2019; panel A), survey year (panel B), and glare (panel C).

Notes: observed data depict mean narwhal group size at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B and C), different letters indicate significant difference between groups.

5.4.2 Group Composition

A qualitative assessment of group composition by life stage recorded in 2019 indicated an overall similar group composition to previous years, with the majority of the sightings consisting of adult whales, followed by the yearling/juvenile category, followed by calves (Figure 5-22). Similar to previous years, both calves and yearlings were observed during most sampling days, with only two days (15 and 28 August 2019) with no calves or yearlings recorded. In 2019, the daily proportion of calves (relative to total narwhal counts) ranged between 0% (on 15 and 28 August) and 19% (on 9 August 2019). The life stage of 487 narwhal (9.1% of all narwhal recorded in the BSA in 2019) was not recorded, due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

In previous years, mean annual percentage of calves ranged between 0% (in all years) and 23-50% (23% in 2014 and 50% in 2017). Annual mean values in 2019 (11.2%) were higher than all previously estimated annual means (2014=10.7%, 2016=9.7%, 2017=7.7%), except for 2015 when a mean annual value of 14% was recorded. The mean proportion of calves recorded in 2019 suggests that calf presence (calving success) at Bruce Head is still occurring at a rate that is consistent with pre-shipping conditions, despite year-over-year increases in shipping in the RSA.

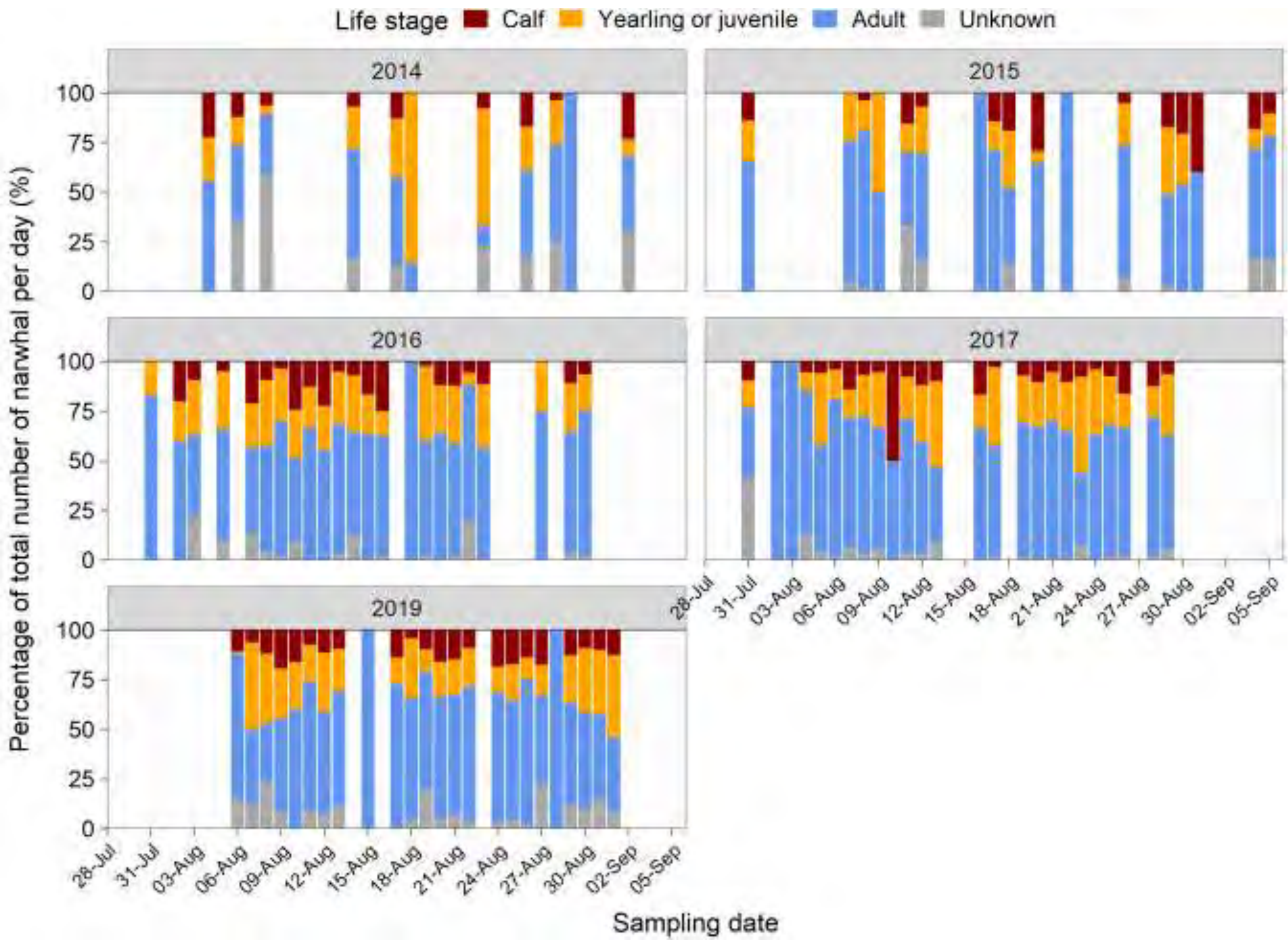


Figure 5-22: Daily summary of narwhal sightings in BSA presented by life stage (2014-2017, 2019).

Based on the group composition classification used in Smith et al. (2017) and as outlined in Section 4.2.2, the most common group composition observed throughout the five years of data collection were groups with 'no observed tusks', whether with or without calves or yearlings (Figure 5-23), accounting for a total of 74% of all narwhal groups observed between 2014-2017 and 2019. Groups with 'no calves or yearlings' accounted for 60% of all observed groups with known composition. The grouping composition of 165 groups (12% of all groups recorded in the BSA in 2019) was not recorded (i.e. "Other" groups), due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

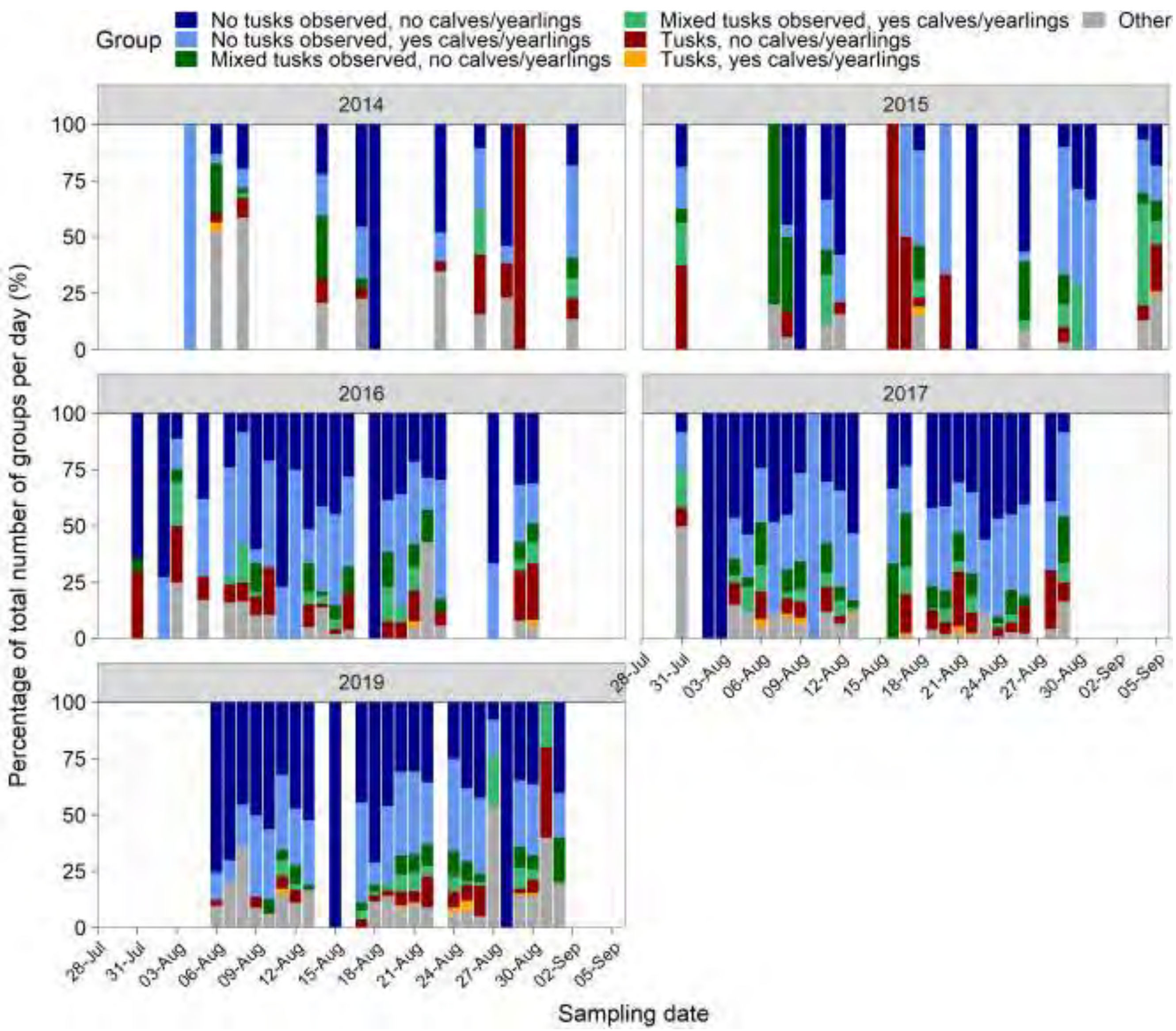


Figure 5-23: Daily distribution of narwhal group composition in BSA (2014–2017, 2019)

The six group types of known composition (shown in Figure 5-23) were grouped further for analysis. To assess the behavioral responses of perhaps the most vulnerable of life stages (i.e. calves, yearlings) to vessel traffic, a separate analysis was conducted on the presence/absence of groups with calves and/or yearlings. The results of this analysis are provided below.

5.4.2.1 Presence of Calves or Yearlings

In the analysis of the presence of calves or yearlings, groups that consisted of a single narwhal were removed, to avoid skewing the analysis results because calves or yearlings were assumed to never be solitary. In the combined 2014–2017 and 2019 dataset, the majority of observations with a group size of 2 or larger and a known group composition were recorded when no vessels were present within 10 km of the BSA (n = 2,829), of which

51% had calves or yearlings (yearly proportion ranged from 37% in 2014 to 56% in 2019). After the removal of single narwhal observations, mean narwhal group size was similar for groups with and without calves or yearlings (4.4 individuals for both; Figure 5-24).

When vessels were present within 10 km from the BSA, 464 groups with and without calves and yearlings were recorded. The percentage of groups with calves or yearlings was similar between the four scenarios of vessel traffic, ranging from 51% when northbound vessels were moving toward the BSA to 58% when southbound vessels were moving toward the BSA. Similar to when no vessels were present within 10 km from the BSA, groups sizes were similar for groups with and without observed calves or yearlings (means of 4.4 individuals and 4.6 individuals, respectively).

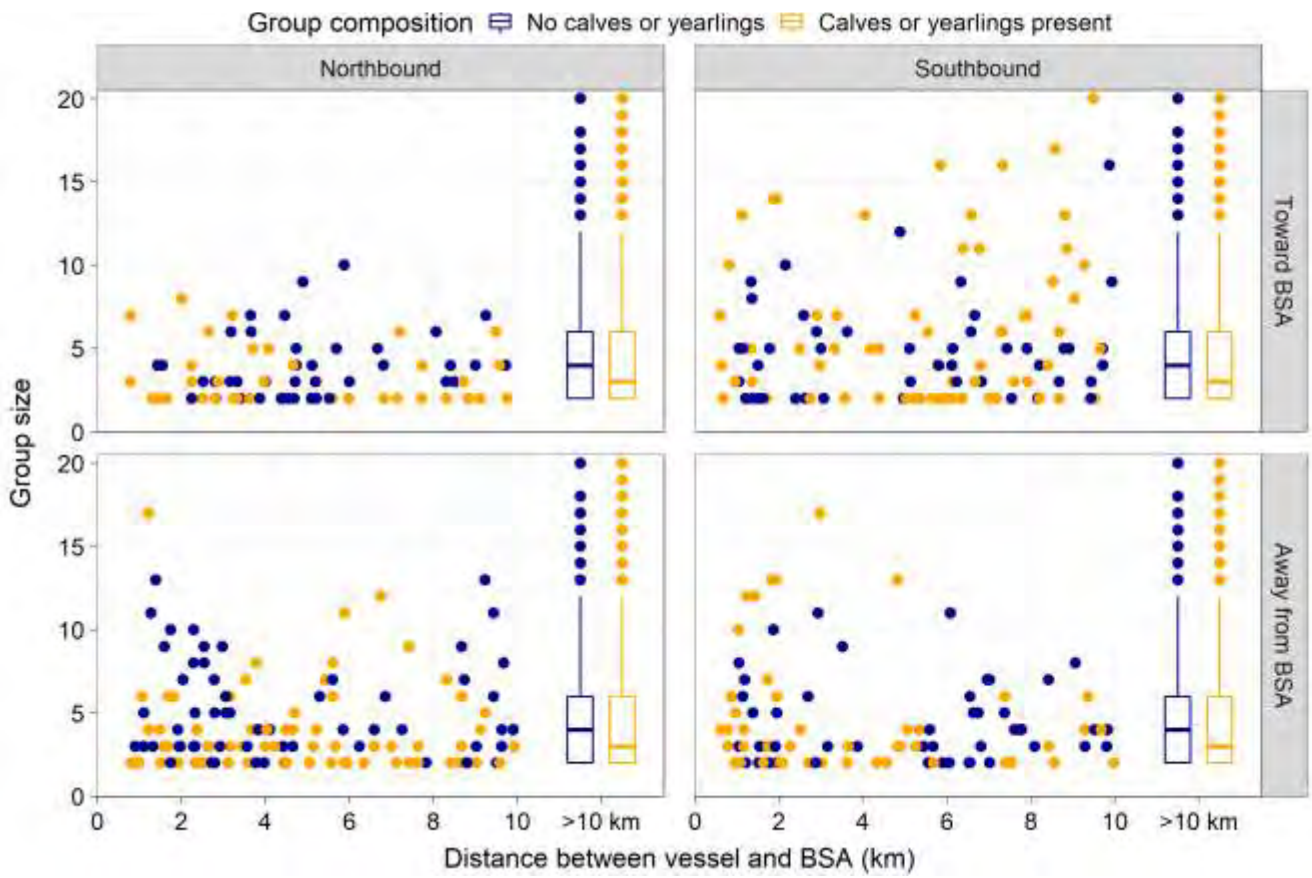


Figure 5-24: Presence/absence of calves and yearlings in narwhal groups of 2 narwhal or more recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

The model of presence of calves or yearlings in groups had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.053. That is, the model's fixed effects explained only 5% of the variability in observing loose groups. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

In the model of presence of calves or yearlings in groups, the effects of group size and glare were statistically significant (*P*<0.001 and *P*=0.027, respectively), as was the three-way interaction between distance from vessel, vessel direction relative to the BSA, and whether the vessel was north- or southbound (*P*=0.003). None of the other effects associated with sampling or effects of hunting or small vessel presences were statistically significant (all *P* values >0.1; Appendix C, Table C-7). The model had low power, and effect sizes of -85% or +230% would be required to detect a significant effect of vessel distance (Appendix E). The power to detect the overall effect of number of vessels within 10 km from the BSA was sufficient (>0.8), however the model did not detect a significant effect of the variable (*P*=0.056).

When a single northbound vessel was travelling toward the BSA, the estimated probability to observe groups with calves or yearlings was relatively low (0.341-0.569) when the vessel was approximately 3-8 km from the BSA, and high (0.750-0.995) when the vessel was in close proximity to the BSA (≤2 km; Figure 5-25). Once the vessel passed the BSA and was moving away from it, the estimated probability to observe groups with calves or yearlings was generally similar (0.586-0.761) until the vessel was approximately 8 km away from the BSA. When a southbound vessel was travelling toward the BSA, the estimated probability to observe groups with calves or yearlings was relatively high (0.699-0.756) while the vessel was approximately 4-8 km away from the BSA, then decreased to 0.548 when the vessel was 3 km away from the BSA. Once the vessel passed the BSA and was moving away from it, the estimated probability to observe groups with calves or yearlings decreased further to 0.471 when the vessel was 5 km away from the BSA. However, none of the multiple comparisons between presence of calves and yearlings when no vessels were present within 10 km to when a single vessel was present at any distance were found to be statistically significant (Table 5-7). These predicted values suggest effect sizes that are large enough to be potentially meaningful, but lack of statistical significance and large 95% confidence intervals in the predictions indicate large uncertainty in the relationship between vessel direction and distance, and calf or yearling presence. Multiple comparisons between 2+ vessels and no vessels were not significantly different at any distance of the nearest vessel (*P*>0.18 for all distances, detail not shown).

The estimated probability to observe calves or yearlings in a group was higher (0.579) for groups of 2 individuals than for groups of 3-11 individuals (probabilities ranging between 0.482 and 0. 551), because many of groups with 2 individuals were mother-calf pairs. With further increase in group size, the probability of observing calves or yearlings increased to 0.732 (group size of 15) and 0.939 (group size of 20).

The effect of glare was statistically significant in the model of observing calves and yearlings. Multiple comparisons of glare levels indicated that the probability of observing calves and yearlings was significantly lower under severe glare than under no glare (0.351 vs 0.508, Figure 5-25). The probability of observing calves and yearlings under low glare (0.456) was not different than either no glare or severe glare.

In summary, the analysis of presence of calves and yearlings using the 2014–2017 and 2019 integrated Bruce Head data supports rejection of the null hypothesis that presence of calves and yearlings do not significantly change during vessel-exposure events.

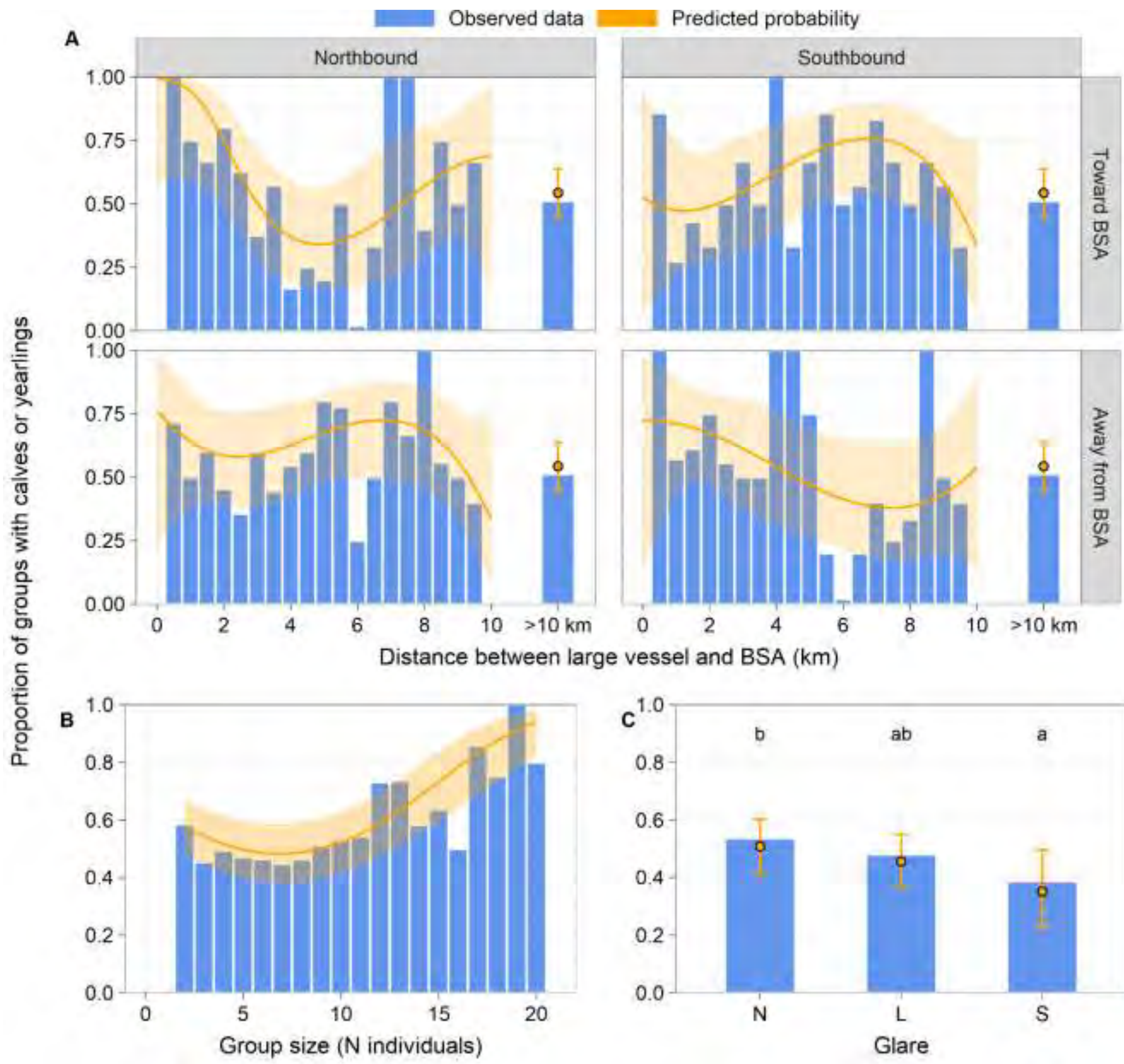


Figure 5-25: Proportion of narwhal groups with calves or yearlings relative to distance from vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017, 2019; panel A), group size (panel B), and glare (panel C).

Notes: observed data depict total proportion of groups observed with calves or yearlings at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panel C), different letters indicate significant difference between groups.

Table 5-7: Multiple comparisons of predictions of observing narwhal groups with calves or yearlings when no vessels are within 10 km from BSA and predictions at specific distances between BSA and vessels; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.995 (0.290)	0.761 (0.937)	0.527 (1.000)	0.725 (0.985)
1	0.945 (0.231)	0.641 (0.953)	0.475 (0.993)	0.712 (0.767)
2	0.750 (0.535)	0.586 (0.992)	0.490 (0.990)	0.673 (0.672)
3	0.503 (0.997)	0.588 (0.992)	0.548 (1.000)	0.613 (0.980)
4	0.370 (0.507)	0.627 (0.907)	0.627 (0.958)	0.541 (1.000)
5	0.341 (0.34)	0.677 (0.581)	0.699 (0.554)	0.471 (0.972)
6	0.381 (0.738)	0.715 (0.432)	0.746 (0.276)	0.414 (0.815)
7	0.467 (0.990)	0.724 (0.509)	0.756 (0.310)	0.383 (0.738)
8	0.569 (1.000)	0.685 (0.733)	0.715 (0.550)	0.385 (0.766)
9	0.652 (0.952)	0.566 (1.000)	0.587 (0.997)	0.433 (0.947)
10	0.689 (0.992)	0.338 (0.864)	0.340 (0.906)	0.539 (1.000)

5.4.3 Group Spread

Based on reports suggesting that narwhal form tight groups as an anti-predator response to killer whale presence in an area (Steltner et al.1984; Laidre et al. 2006; Breed et al. 2017), it was predicted that narwhal may form tight groups in response to other potential perceived threats (i.e., vessel traffic). Therefore, narwhal groups of two or more individuals were classified as tight (i.e., individuals ≤1 body width apart) or loose (i.e., individuals >1 body width apart) based on the physical proximity of individuals to one another. In 54 cases (3.9% of the 2019 data), group spread was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Throughout the five years of sampling, narwhal were more often observed in tight groups than in loose groups (Figure 5-26), regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2015, 2016, 2017; Golder 2018, 2019).

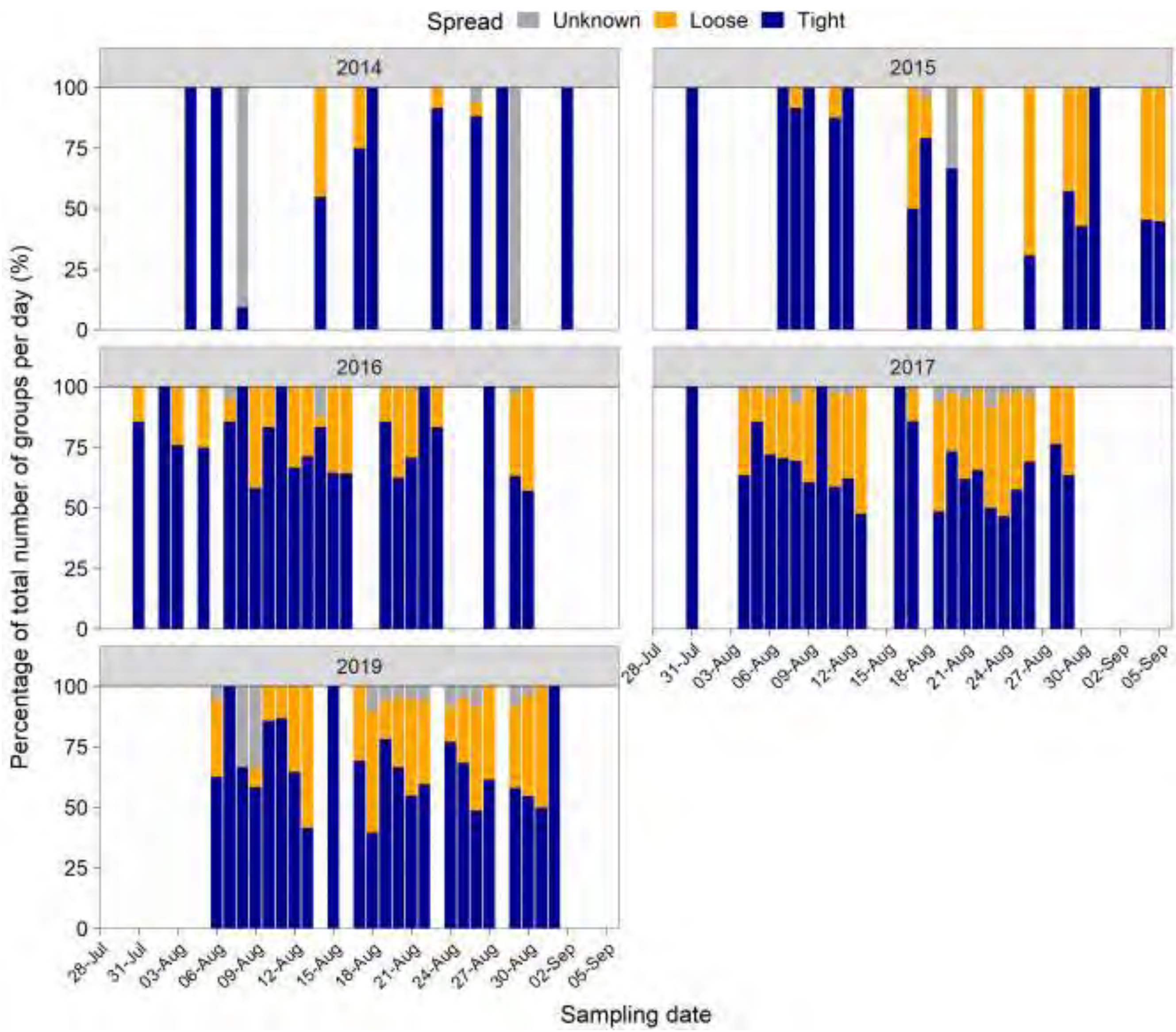


Figure 5-26: Daily distribution of groupings of narwhal group spread (2014–2017, 2019)

In the combined 2014–2017 and 2019 dataset, the majority of narwhal group spread observations were recorded when no vessels were present within 10 km of the BSA (n = 3,243), of which 34% were in loose spread (annual percentage ranging from 23% in 2014 to 38% in 2015 and 37% in 2017). Mean narwhal group size was larger for loose-spread groups than for tight groups (4.8 and 4.2 individuals, respectively; Figure 5-27).

When vessels were present within 10 km from the BSA, 542 groups with a known spread were recorded. Groups in loose spread were less common when vessels headed away from the BSA (32% for northbound vessels and 30% for southbound vessels) than when vessels were heading toward the BSA (38% for northbound vessels and 32% for southbound vessels). Similar to when no vessels were present within 10 km from the BSA, loose groups were on average larger (mean of 5.2 individuals) than tight groups (mean of 4.2 individuals).

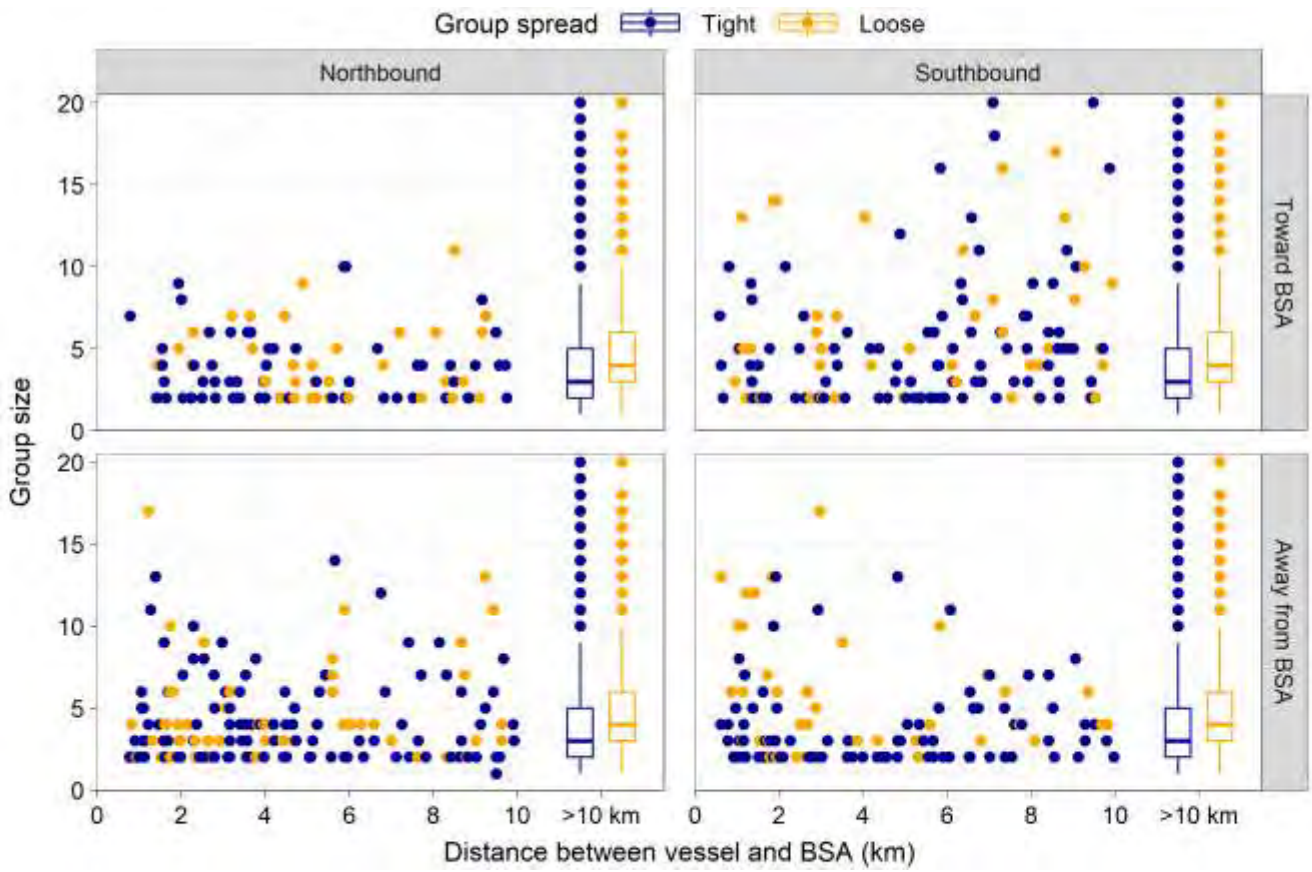


Figure 5-27: Group spread of narwhal groups observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

The model had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.06. That is, the model's fixed effects explained only 6% of the variability in observing loose groups, indicating that variability in group spread may not be explainable by the available fixed predictor variables. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

In the model of group spread, none of the shipping-related variables (distance from vessel, vessel direction within Milne Inlet or vessel direction relative to the BSA) were statistically significant (P=0.093 for presence of vessels within 10 km from BSA, and P>0.4 for all other shipping-related effects; Appendix C, Table C-9). The effects of survey year (P<0.001), group size (P<0.001), and hunting activity (P=0.023) were statistically significant in the model of group spread. Multiple comparisons of survey years indicated that the probability of groups in loose spread was not significantly different in 2019 than 2015, 2016, or 2017, but was significantly greater than 2014 (Figure 5-21). The model had low power, and effect sizes of -80% or +170% would be required to detect a significant effect of vessel distance (Appendix E). The power to detect the overall effect of number of vessels within 10 km from the BSA was low, requiring a +250% effect size to detect a significant effect of the variable.

The population-level estimate of the probability of observing groups in loose spread increased with increasing group size, from 0.3 at a group size of 3 individuals, to 0.55 at a group size of 15 individuals (Figure 5-21).The estimated population-level probability of observing groups in loose spread immediately following hunting was slightly lower (e.g., probability of 0.210 at 0 min post shooting) than when no hunting occurred within the 3 h preceding the survey (probability of 0.298). No abrupt change in group spread was evident immediately after hunting, suggesting that the slightly higher probability to observe narwhal in a tight spread during hunting activity was likely the cause, rather than the effect, of hunting. Statistical comparisons of the probability of observing groups in a loose spread at 10 min increments following a shooting event to the probability when no hunting occurred within the preceding 3 h did not find significant differences ($P>0.1$ for all comparisons).

In summary, the 2014–2017 and 2019 integrated Bruce Head data do not support rejection of the null hypothesis that group spread does not significantly change during vessel-exposure events. That is, findings did not suggest that narwhal either congregate into tight groups or disperse into loose groups as a potential anti-predator response to vessel traffic. However, the power to detect an effect of vessel distance was low, requiring a large effect size to reliably detect a significant effect.

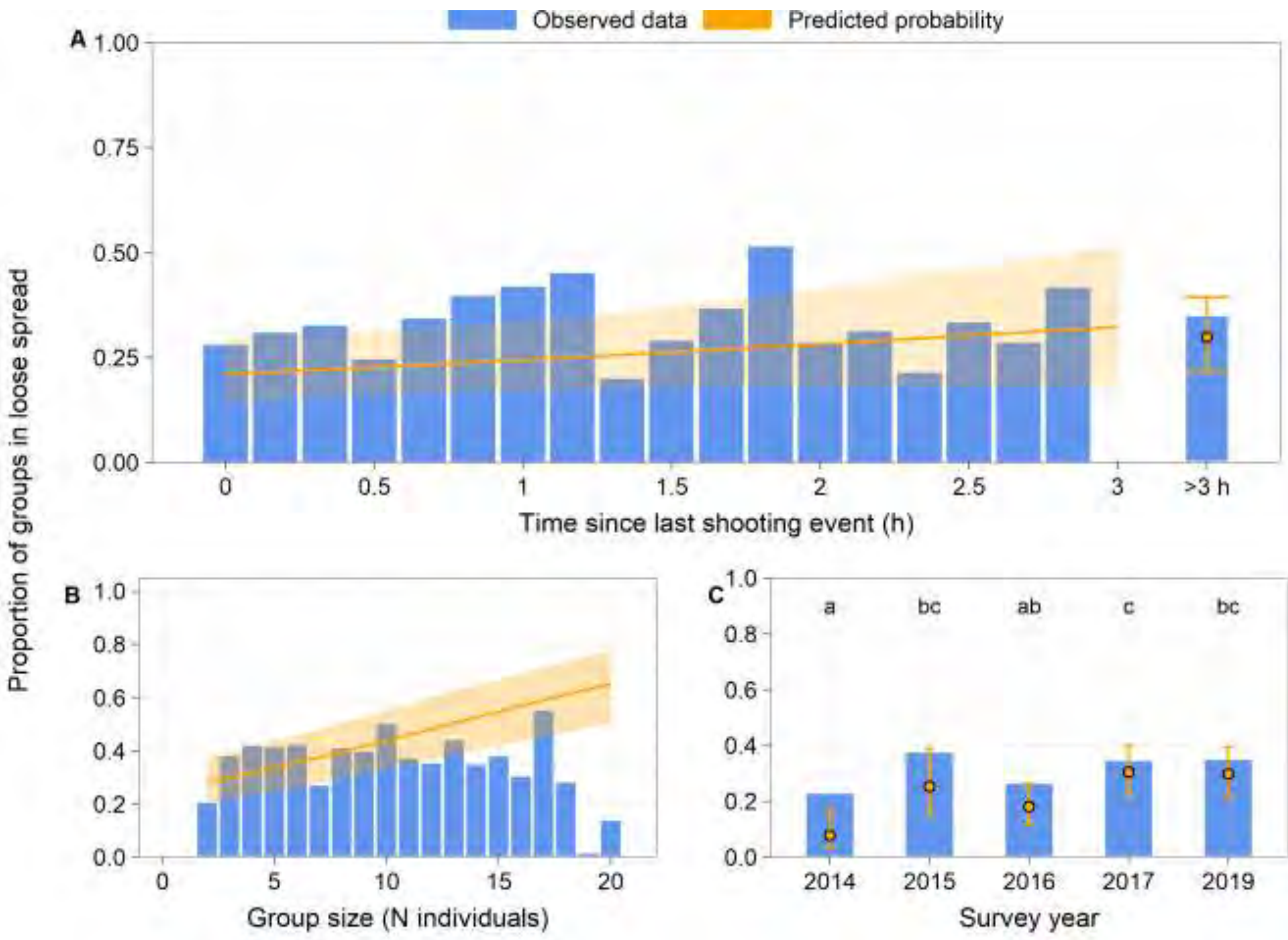


Figure 5-28: Proportion of narwhal groups observed in a loose spread (rather than tight spread) relative to time since hunting (panel A), group size (panel B), and survey year (panel C), 2014–2017, 2019

Notes: observed data depict total proportion of groups observed a loose spread (rather than at tight spread) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels C), different letters indicate significant difference between groups.

5.4.4 Group Formation

As knowledge regarding the context and function (if any) of narwhal aggregations is generally incomplete (Marcoux et al. 2009), monitoring of narwhal group formation is warranted to better understand whether a given formation is indicative of a potential response to a perceived threat (i.e., a transiting vessel). The formation of narwhal groups of two or more individuals observed in the BSA during 2014–2017 and 2019 sampling years was classified as linear, parallel, cluster, non-directional line, or no formation. The majority of recorded groups in the five years of sampling were in the parallel formation, followed by cluster formation (Figure 5-29), regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2015, 2016, 2017; Golder 2018, 2019). In 58 cases (4.2% of the 2019 data), group formation was not recorded, due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Parallel groups comprised 12%, 34%, 33%, 49%, and 23% of all daily recorded groups of two or more individuals in 2014–2017 and 2019, respectively. Cluster groups comprised 7%–13% of all daily groups, depending on year. Conversely, linear groups comprised only 1%–6% of all groups recorded within the year, and only up to 10%, 33%, 17%, and 38% of all daily groups in 2014, 2016, 2017, and 2019 (with a single day in 2015 with 100% linear formation, where only one group of narwhal with two or more individuals was recorded in the BSA).

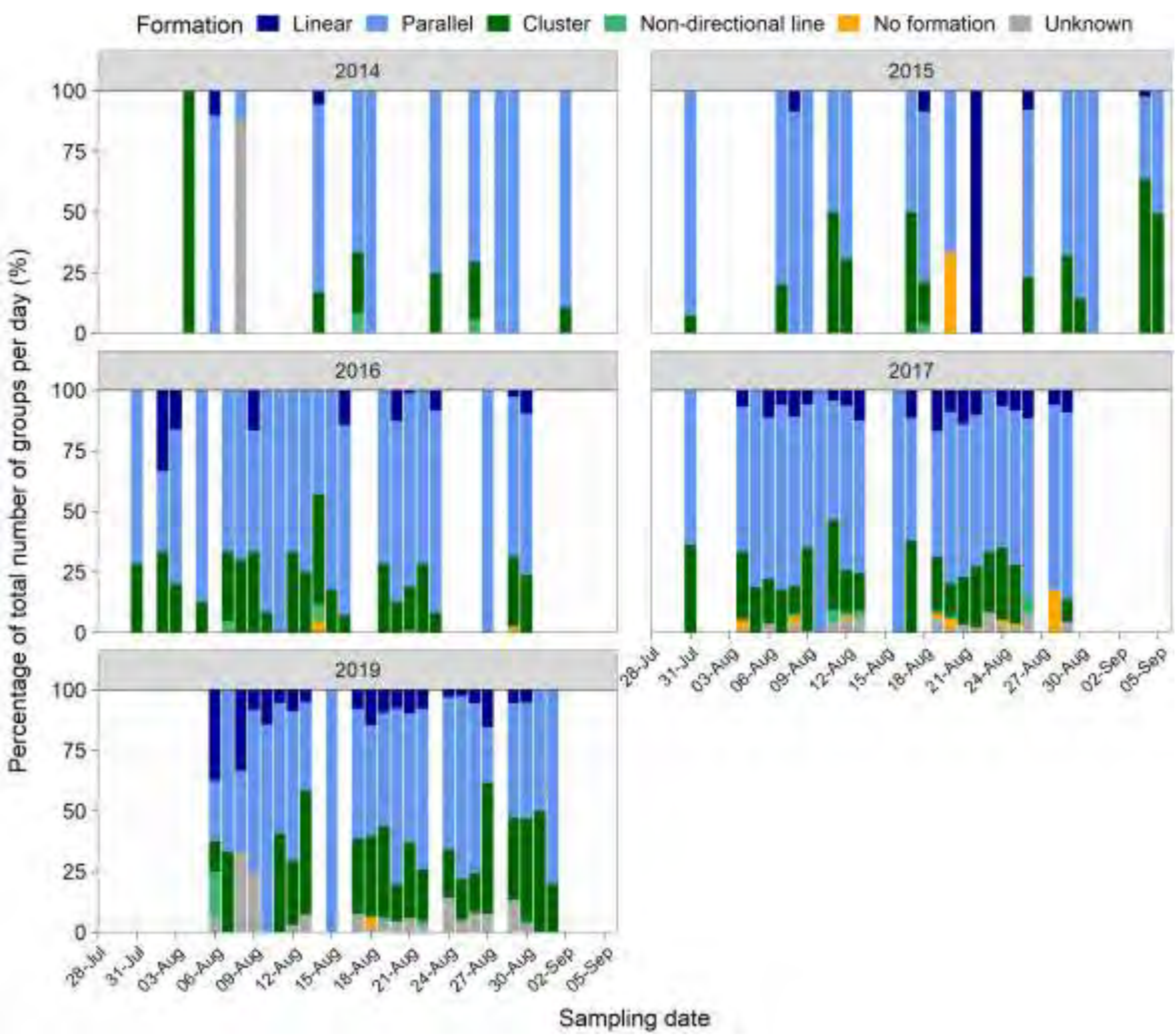


Figure 5-29: Daily distribution of groupings of narwhal group formation (2014–2017, 2019)

In the combined 2014–2017 and 2019 dataset, the majority of narwhal group formation observations were recorded when no vessels were present within 10 km of the BSA (n = 3,244), of which 36% were in non-parallel formation (annual percentage ranging from 19% in 2014 to 42% in 2019). Mean narwhal group size was larger for non-parallel groups than for groups in parallel formation (5.7 and 3.7 individuals, respectively; Figure 5-30).

When vessels were present within 10 km from the BSA, 538 groups with a known formation were recorded. The lowest percentage of groups in non-parallel formation was recorded during the passage of southbound vessels, when they were heading away from BSA (27%). The highest percentage was recorded during the passage of southbound vessels when they were heading toward the BSA (36%). Percentages were similar between northbound vessels that were heading toward the BSA (34%) or away from the BSA (31%). Similar to when no vessels were present within 10 km from the BSA, non-parallel groups were on average larger (mean of 6.6 individuals) than groups in parallel formation (mean of 3.6 individuals).

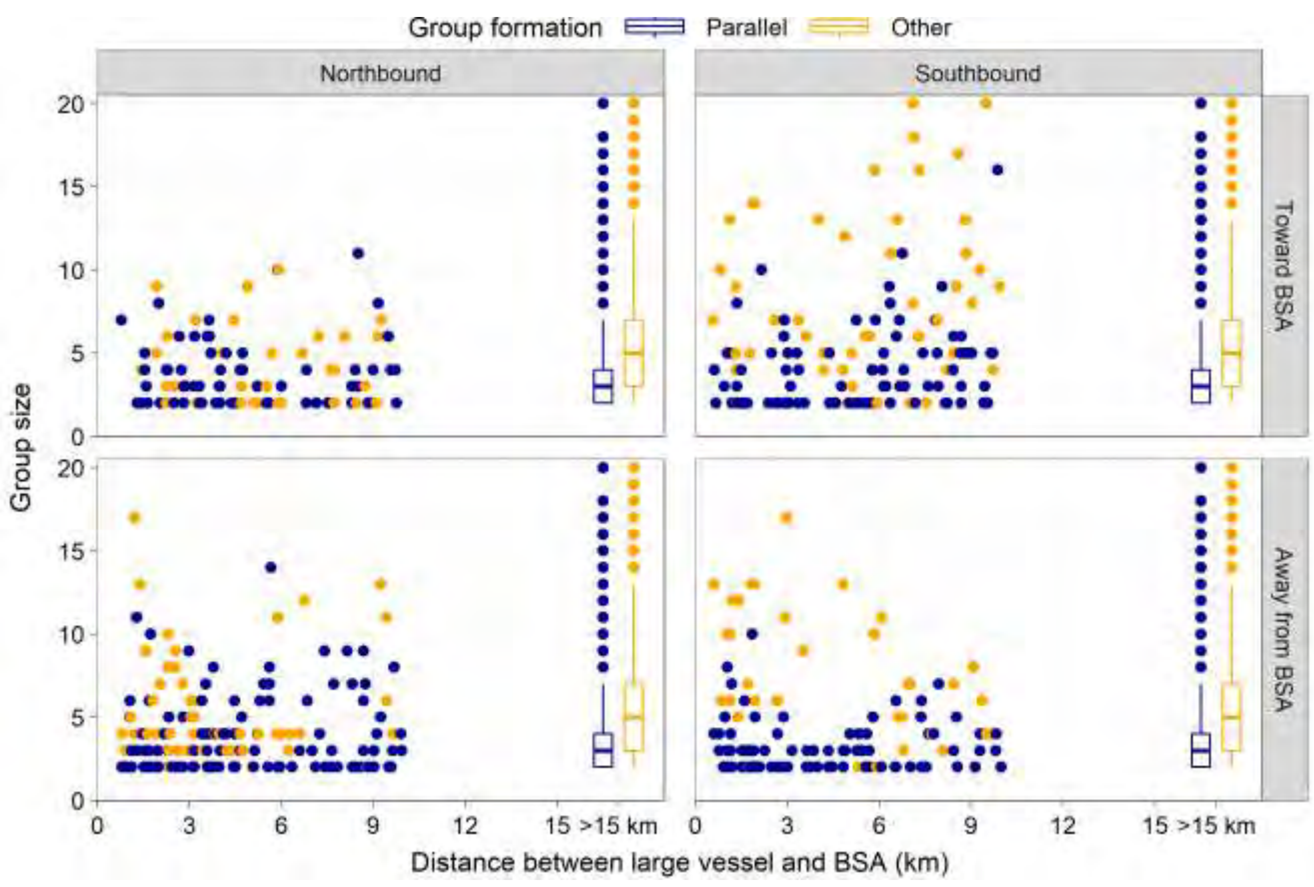


Figure 5-30: Group formation of narwhal recorded in BSA relative to group size and distance from vessels transiting through the SSA (2014–2017, 2019)

The model had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.241. That is, the model's fixed effects explained approximately 24% of the variability in observing south-travelling groups. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

In the model of group formation, none of the shipping-related variables (distance from vessel, vessel direction within Milne Inlet, vessel direction relative to the BSA, or their interaction) were statistically significant (P>0.07 for all effects; Appendix C, Table C-11). Hunting and the presence of small vessels were not statistically significant predictors of group formation. The effects of survey year (P<0.001), group size (P<0.001), glare (P<0.001) and Beaufort scale (P=0.02) were statistically significant in the model of group formation. The model had low power, and effect sizes of -90% or +160% would be required to detect a significant effect of vessel distance (Appendix E). The power to detect the overall effect of number of vessels within 10 km from the BSA was low, and none of the effect sizes examined (from -100% to +300%) resulted in sufficient (>0.8) power.

Multiple comparisons of survey years indicated that the proportion of groups in non-parallel formation was not different between any years from 2015-2017 and 2019, but was significantly lower in 2014 (Figure 5-31). Multiple comparisons between levels of the Beaufort scale indicated a significantly a greater proportion of groups in non-parallel formation at level 2 than level 3, but none of the other comparisons between levels of the Beaufort scale were significant, suggesting that this was a spurious effect. The proportion of groups in non-parallel formation was significantly greater during “severe glare” (0.53 non-parallel formation) than during “low glare” or “no glare” (0.30 and 0.28, respectively). There was a strong effect of group size on the proportion of groups in non-parallel formation, with population-level estimates increasing from 0.22 at 2 individuals to 0.9 at 13 individuals, and 0.99 at 20 individuals.

Although none of the shipping-related variables were statistically significant, the interaction between vessel distance, direction relative to BSA, and direction within Milne Inlet (north or south) was marginally significant (P=0.07). Plots of population-level estimates suggested possible effects of vessel distance on group formation for some of the vessel directions (Figure 5-31). For instance, when vessels were southbound and travelling away from the BSA, the proportion of groups in non-parallel formation increased from 0.13 at a vessel distance of 0 km to 0.27 at a vessel distance of 7 km, and was 0.28 when vessels were more than 10 km away. However, none of the multiple comparisons between group formation at 0 km and group formation at any other vessel distance indicated statistically significant differences (Table 5-8). Multiple comparisons between no vessels and a scenario of 2+ vessels where the nearest vessel was at various distances from BSA were not significantly different at any distance (P>0.3 for all distances). These predicted values suggest effect sizes that are large enough to be potentially meaningful, but lack of statistical significance and large 95% confidence intervals in the predictions indicate large uncertainty in the relationship between vessel direction and distance, and group formation.

In summary, the 2014–2017 and 2019 integrated Bruce Head data suggested a possible but uncertain effect of vessel distance on group formation that depended on the vessel direction, with the most consistent effect suggested for southbound vessels moving away from the BSA. However, these results were not strong enough to support rejection of the null hypothesis that group formation does not significantly change during vessel-exposure events.

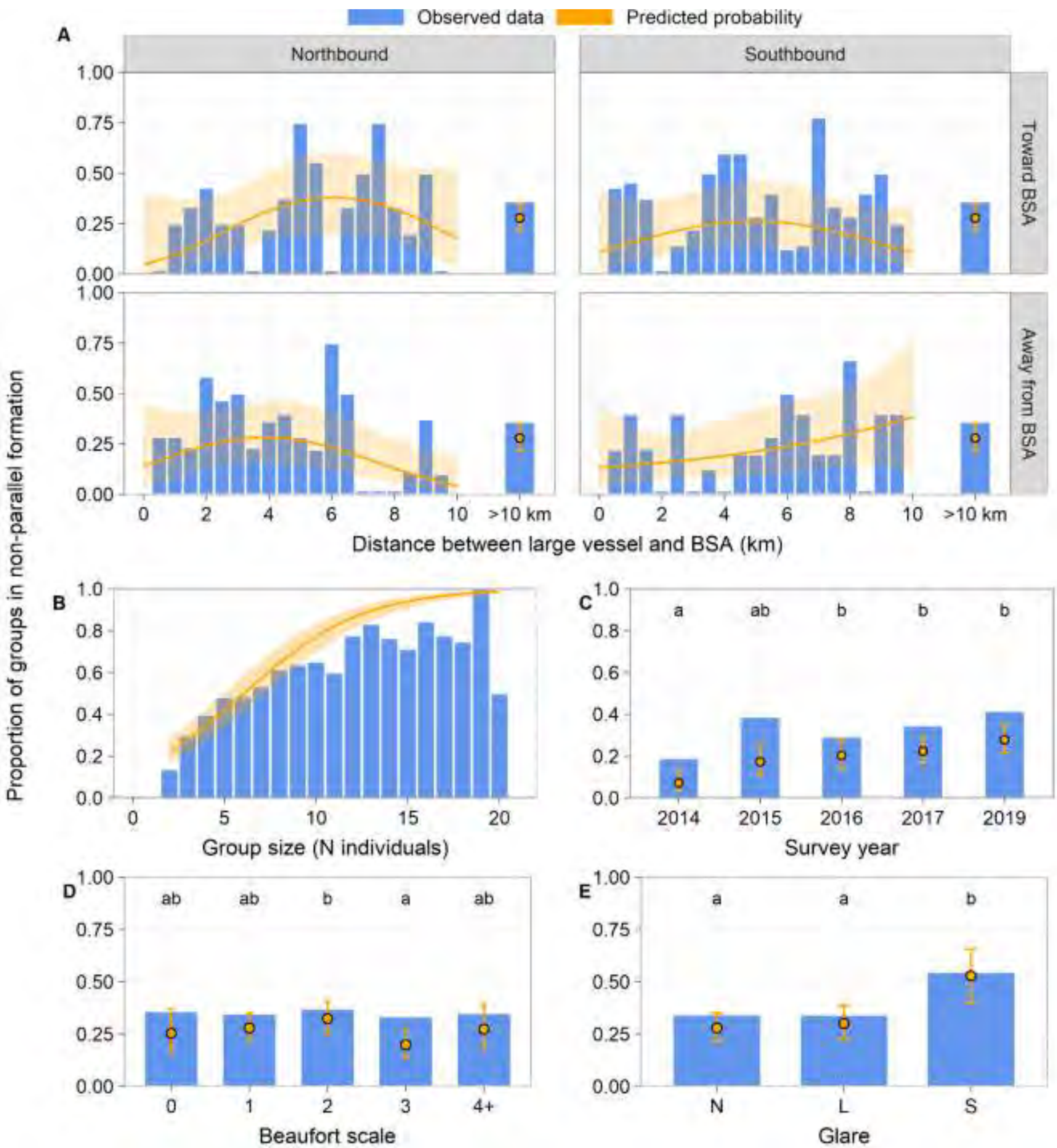


Figure 5-31: Proportion of narwhal groups observed in a non-parallel formation relative to distance from vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017, 2019; panel A), group size (panel B), survey year (panel C), Beaufort scale (panel D), and glare (panel E).

Notes: observed data depict total proportion of groups observed in non-parallel formation at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B and C), different letters indicate significant difference between groups.

Table 5-8: Multiple comparisons of predictions of observing narwhal groups in not-parallel formation when no vessels are within 10 km from BSA and predictions at specific distances between BSA and vessels; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.048 (0.568)	0.141 (0.852)	0.110 (0.736)	0.134 (0.854)
1	0.097 (0.614)	0.195 (0.920)	0.154 (0.751)	0.145 (0.619)
2	0.166 (0.780)	0.242 (0.989)	0.197 (0.852)	0.158 (0.410)
3	0.244 (0.994)	0.272 (1.000)	0.233 (0.976)	0.173 (0.575)
4	0.314 (0.996)	0.281 (1.000)	0.256 (0.999)	0.192 (0.841)
5	0.362 (0.925)	0.267 (1.000)	0.263 (1.000)	0.213 (0.960)
6	0.380 (0.868)	0.233 (0.978)	0.254 (0.999)	0.238 (0.995)
7	0.367 (0.903)	0.184 (0.663)	0.229 (0.971)	0.268 (1.000)
8	0.323 (0.993)	0.129 (0.197)	0.192 (0.771)	0.301 (1.000)
9	0.256 (1.000)	0.08 (0.095)	0.148 (0.544)	0.340 (0.992)
10	0.178 (0.974)	0.044 (0.102)	0.105 (0.515)	0.383 (0.986)

5.4.5 Group Direction

The majority of narwhal groups observed in the BSA during 2014–2017 and 2019 sampling years travelled in the south direction (Figure 5-32), toward Koluktoo Bay and Milne Port, with annual averages of daily percentages of south-travelling groups ranging between 64% (in 2016) and 90% (in 2015). In 2019, the annual average of daily percentages of south-travelling groups was 59%. Annual averages of daily percentages of north-travelling groups ranged between 40% (in 2017) and 59% (in 2014). In 2019, the annual average of daily percentages of north-travelling groups was 42%. In 46 cases (3.4% of the 2019 data), group direction was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Both east and west travel directions were rare, with annual averages between 2% and 15%, depending on direction and year.

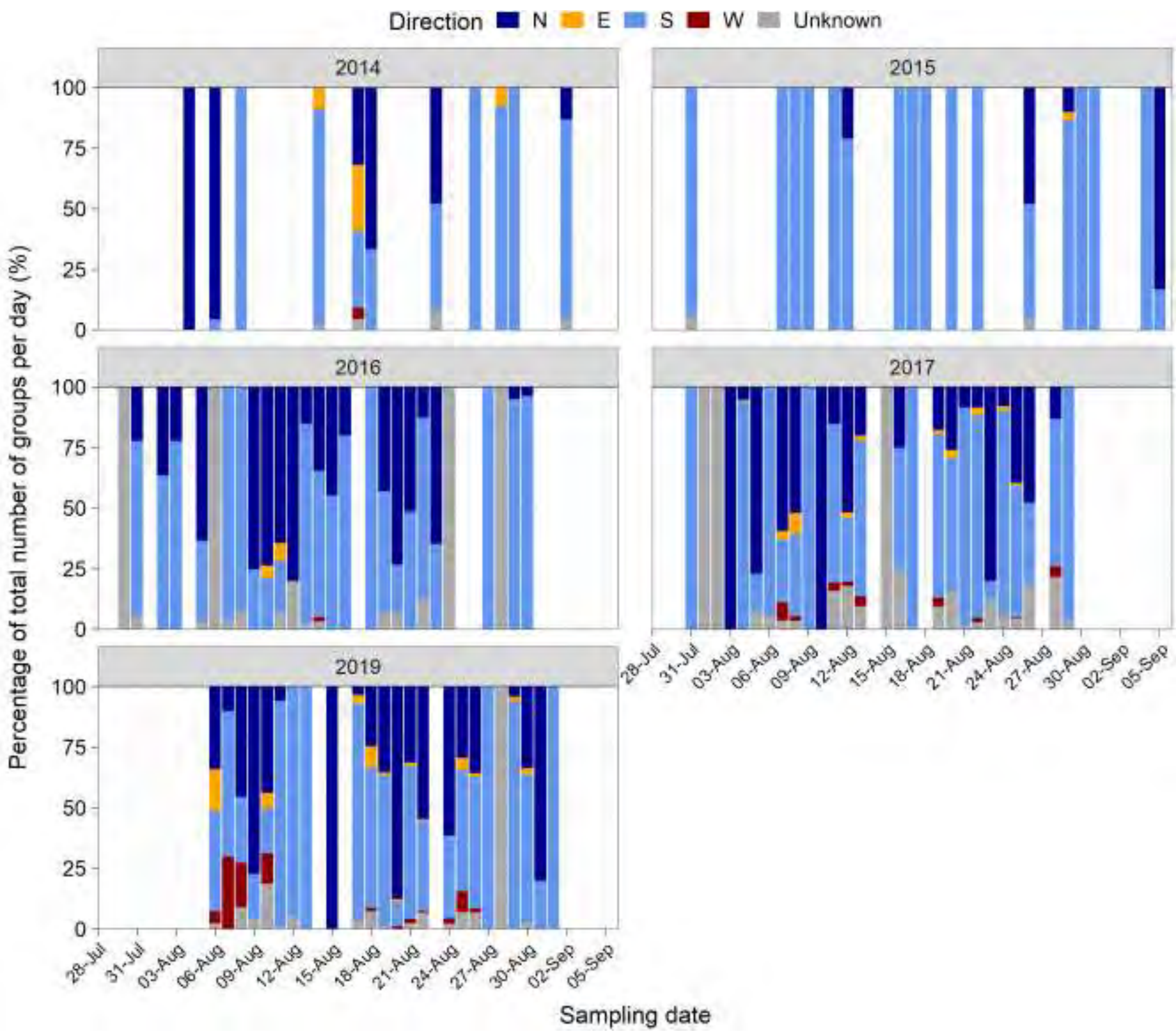


Figure 5-32: Daily distribution of narwhal group travel direction in BSA (2014–2017, 2019)

The direction that narwhal groups are observed travelling through the BSA in relation to vessel traffic may inform whether animals actively move away from, or potentially avoid, vessels transiting along the Northern Shipping Route. In the combined 2014–2017 and 2019 dataset, the majority of narwhal group travel direction observations (filtered to north/south travel only) were recorded when no vessels were present within 10 km of the BSA (n = 3,994), of which 69% travelled south and 31% travelled north. Annual percentage of south-travelling groups ranged from 61% in 2015 to 80% in 2014. Mean narwhal group size was larger for south-travelling groups than for north-travelling groups (4.2 and 2.6 individuals, respectively; Figure 5-33).

When vessels were present within 10 km from the BSA, 627 groups with a known travel direction were recorded. South-travelling groups were least common when southbound vessels were headed away from BSA (38%) than when vessels were moving toward BSA (69% and 77%% for northbound and southbound vessels, respectively). South-travelling groups were most prevalent when northbound vessels were moving away from the BSA (93%). Similar to when no vessels were present within 10 km from the BSA, south-travelling groups were on average larger (mean of 4.3 individuals) than north-travelling groups (mean of 3.2 individuals).

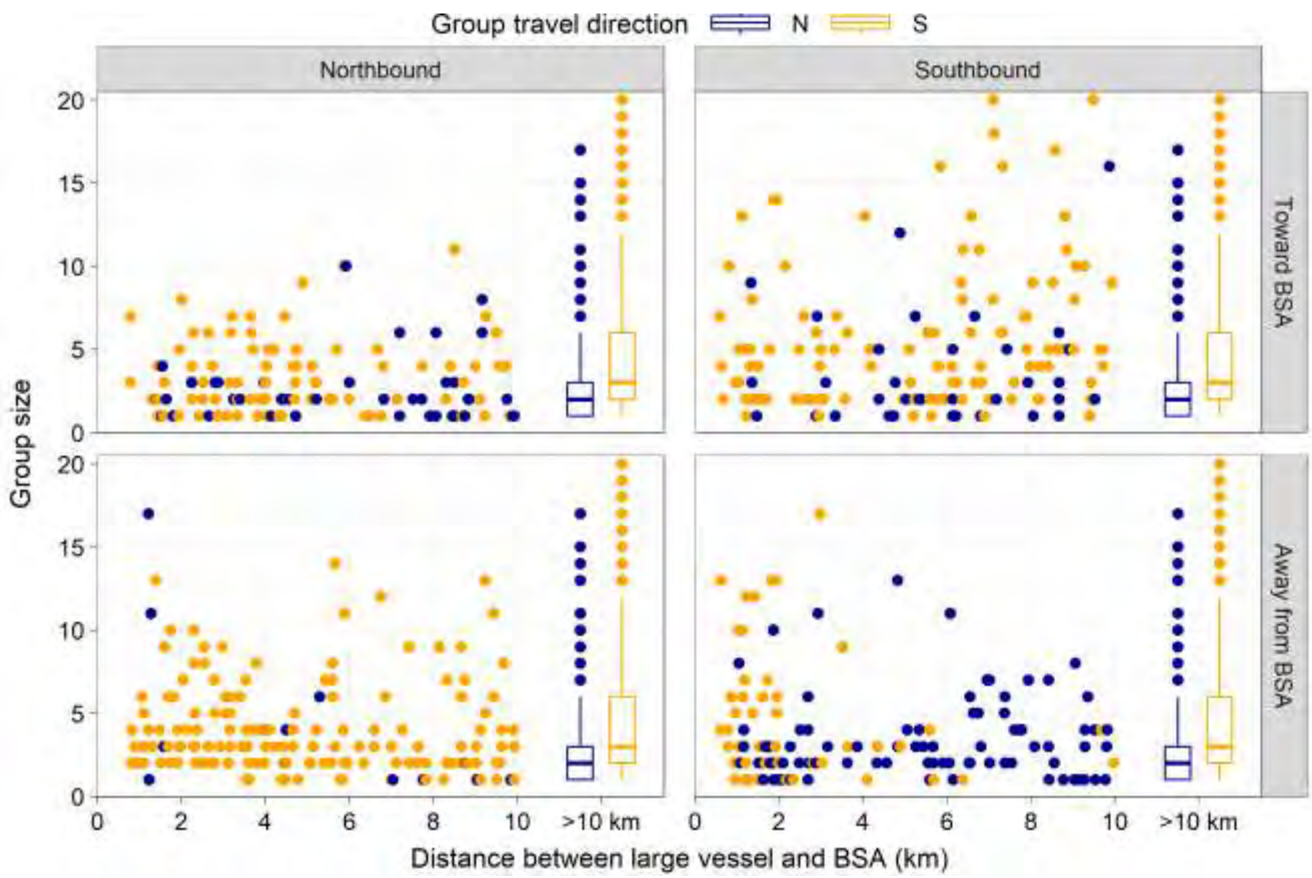


Figure 5-33: Group travel direction of narwhal groups observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

The model had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.658. That is, the model's fixed effects explained approximately 66% of the variability in observing south-travelling groups. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

In the model of group direction, Beaufort Scale was statistically significant (P=0.02), and distance from vessel was significant (P=0.05). None of the other variables were statistically significant predictors of group direction (Appendix C, Table C-13). The model had low power to detect the observed effect sizes (Appendix E), however it did detect the overall effect of vessel distance on group direction. The power to detect the overall effect of number of vessels within 10 km from the BSA was low, and none of the effect sizes examined (from -100% to +300%) resulted in sufficient (>0.8) power.

Multiple comparisons between levels of the Beaufort scale indicated a significantly a greater probability of observing groups travelling south at levels 2 and 3 (probabilities of 0.98 and 1.0, respectively) than level 1 (0.79) but no other significant differences between levels of the Beaufort scale. The lack of a consistent change in the response variable relative to Beaufort scale suggests that the sea state had a fairly small effect on group direction.

Population-level estimates of group direction generally showed an increasing probability of narwhal groups to travel south with a decreasing distance from vessels (Figure 5-34). When vessels were northbound and travelling toward the BSA, the probability to observe groups travelling south decreased from 0.99 at 0 km to 0.89 at 5 km, compared to 0.79 when no vessels were within 10 km from the BSA. However, confidence intervals around the population-level estimates were very large, for example, ranging from 0.2 to 1.0 at a distance of 5 km. Similarly, when a southbound vessel was moving away from the BSA, the probability to observe groups travelling south decreased from 0.99 at 0 km to 0.32 at 5 km, with both estimates having high uncertainty. As a result of the high uncertainty, none of the multiple comparisons between group direction at various distances from vessels and group direction when no vessels were present were statistically significant (Table 5-9). These results indicate a possible, though uncertain relationship between group direction and distance from vessel. Lack of statistical significance of the interactions between vessel distance, direction relative to BSA, and direction within Milne Inlet (north or south), suggests that the effect of vessel distance on group direction did not depend on the direction the vessel was travelling. Multiple comparisons between 2+ vessels where the nearest vessel was at various distances km from BSA and no vessels were not statistically significant for any distance (P>0.5 for all distances).

In summary, the 2014–2017 and 2019 integrated Bruce Head data suggested a possible but uncertain effect of vessel distance on narwhal group direction. The results support rejection of the null hypothesis that group direction does not significantly change during vessel-exposure events.

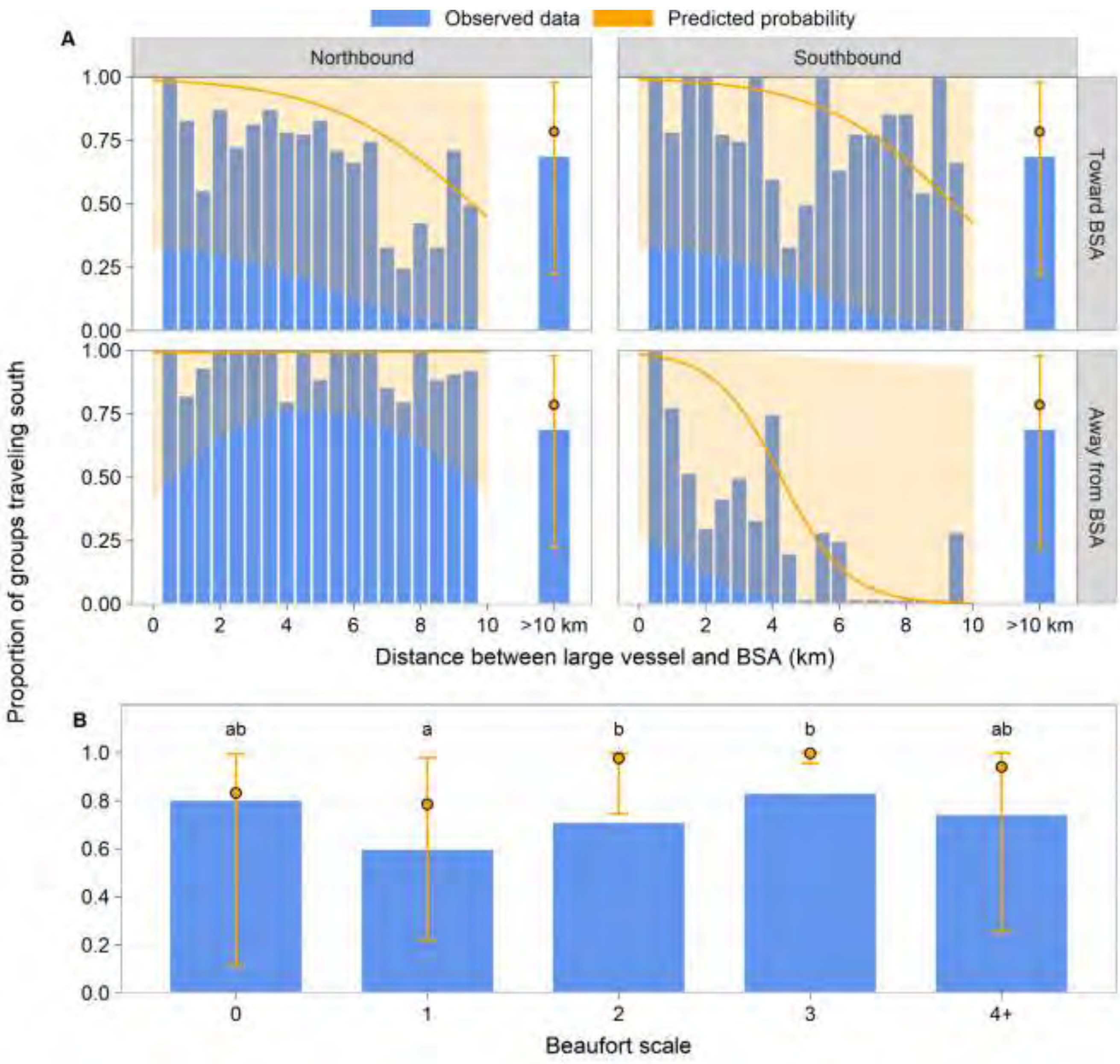


Figure 5-34: Proportion of narwhal groups observed travelling south relative to distance from vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017, 2019; panel A) and Beaufort scale (panel B).

Notes: observed data depict total proportion of groups observed travelling south at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panel B), different letters indicate significant difference between groups.

Table 5-9: Multiple comparisons of predictions of observing narwhal groups travelling south when no vessels are within 10 km from BSA and predictions at specific distances between BSA and vessels; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.987 (0.711)	0.992 (0.608)	0.991 (0.683)	0.986 (0.778)
1	0.980 (0.748)	0.992 (0.450)	0.986 (0.718)	0.964 (0.901)
2	0.969 (0.799)	0.993 (0.296)	0.977 (0.770)	0.907 (0.988)
3	0.952 (0.865)	0.994 (0.184)	0.962 (0.840)	0.781 (1.000)
4	0.926 (0.935)	0.994 (0.129)	0.938 (0.921)	0.565 (0.983)
5	0.888 (0.985)	0.995 (0.121)	0.902 (0.98)	0.322 (0.868)
6	0.835 (1.000)	0.995 (0.153)	0.848 (0.999)	0.148 (0.717)
7	0.762 (1.000)	0.996 (0.222)	0.771 (1.000)	0.060 (0.606)
8	0.607 (0.996)	0.996 (0.321)	0.670 (0.998)	0.023 (0.536)
9	0.563 (0.976)	0.996 (0.433)	0.551 (0.985)	0.008 (0.493)
10	0.450 (0.939)	0.997 (0.539)	0.426 (0.958)	0.003 (0.465)

5.4.6 Travel Speed

In assessing the effect of vessel exposure on narwhal travel speed, it was predicted that slow travel speed may be indicative of narwhal exhibiting a “freeze response” while fast travel speed may indicate an avoidance response. The majority of narwhal groups observed in the BSA during 2014-2017 and 2019 sampling years travelled at a medium speed, whereas slow speeds was the next most common travel speed (Figure 5-35). Annual averages of daily percentages of groups travelling at a medium speed ranged between 40% (in 2019) and 80% (in 2014). Annual averages of daily percentages of slow-speed groups ranged between 30% (in 2017) and 46% (in 2015); the 2019 average value was 36%. Fast-travelling groups were relatively rare, with annual averages of 9%, 57%, 24%, 16%, and 21% in 2014-2017 and 2019, respectively. In 2019, the distribution of groups moving at slow and medium speeds was more even than in previous years, with 36% and 40% annual averages of daily percentages, respectively. In 58 cases (4.2% of the 2019 data), travel speed was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity.

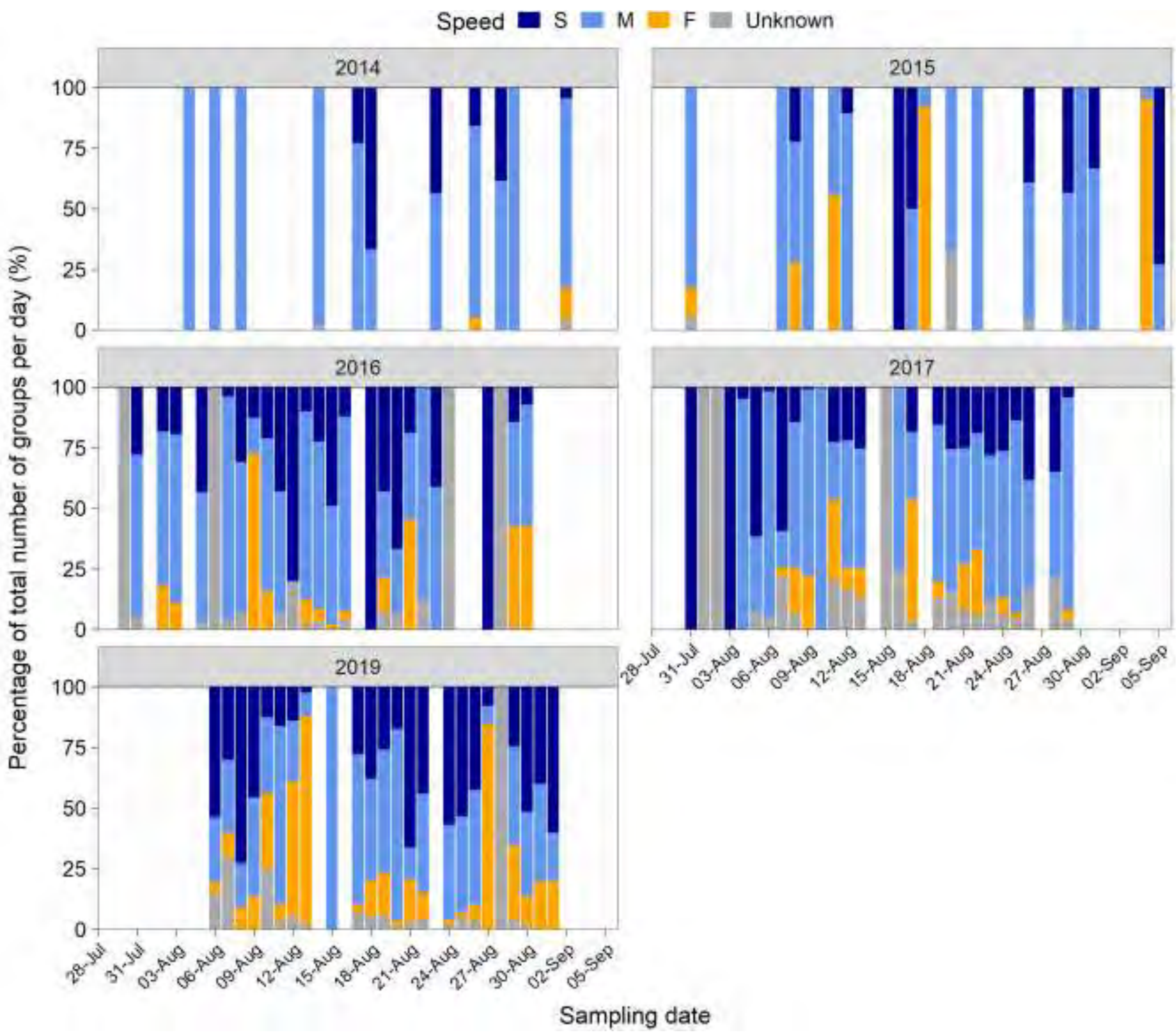


Figure 5-35: Daily distribution of narwhal group travel speed in BSA (2014–2017, 2019)

The travel speed of narwhal groups from the Bruce Head shore was analyzed in relation to proximity and orientation of transiting vessels (Figure 5-36). In the combined 2014–2017 and 2019 dataset, the majority of observations of narwhal travel speed Bruce Head were recorded when no vessels were present within 10 km of the BSA (n = 4,078), of which 28% were travelling slowly, 58% were travelling at a medium speed, and only 15% were travelling fast. Mean narwhal group size was smallest for slow groups (2.8 individuals), intermediate for medium speed groups (3.9 individuals), and largest for fast groups (4.6 individuals).

When vessels were present within 10 km from the BSA, 649 groups with a known travel speed were recorded. The percentage of groups travelling slowly varied with vessel direction and direction relative to the BSA, ranging from 16% for northbound vessels heading away from the BSA to 30% for southbound vessels heading away from the BSA. The percentage of groups travelling at a fast speed ranged from 13% for northbound vessels heading toward the BSA to 45% for southbound vessels heading toward the BSA. Similar to when no vessels were present within 10 km from the BSA, travel speed and group size were positively related, with mean group size increasing from 2.8 individuals for slow groups to 3.9 individuals for medium speed groups to 4.8 individuals for fast groups.

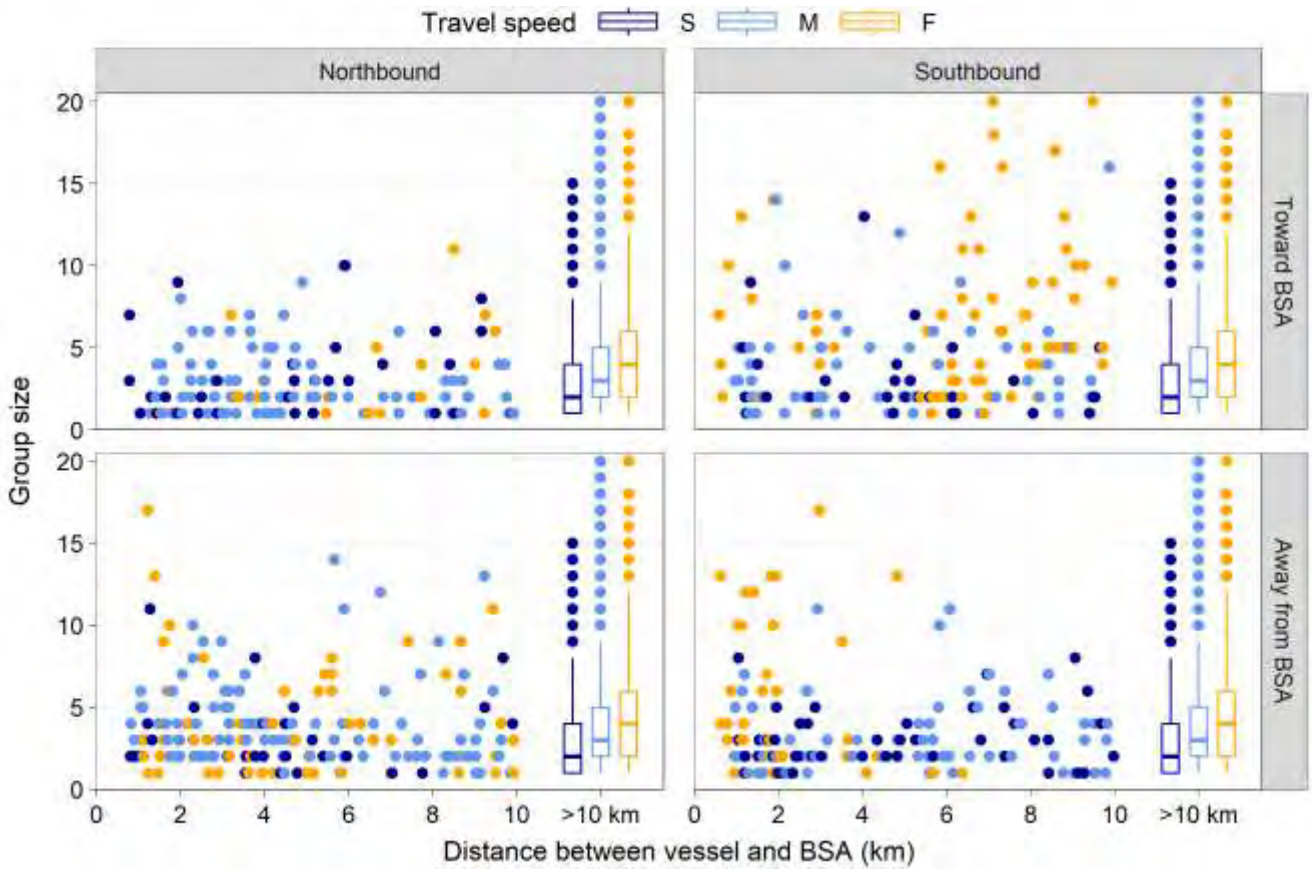


Figure 5-36: Travel speed of narwhal groups recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

5.4.6.1 Slow-travelling groups

The model had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.237. That is, the model's fixed effects explained approximately 24% of the variability in observing slow-travelling groups. Test statistics and coefficient estimates for the model are provided in Appendix C.

In the model predicting the proportion of groups travelling slow (out of groups travelling at slow and medium speed), the effects of group size (P<0.001), survey year (P=0.001), and Beaufort scale (P=0.03) were statistically significant. None of the other variables were statistically significant predictors of the proportion of groups travelling slow (Appendix C, Table C-15). Residual diagnostic plots are provided in Appendix D. The model had low power to detect the observed effect sizes, and effect size of -90% or +200% were required for sufficient power (Appendix E). The power to detect the overall effect of number of vessels within 10 km from the BSA was low, and none of the effect sizes examined (from -100% to +300%) resulted in sufficient (>0.8) power.

There was a strong negative effect of group size on travel speed, with the population-level estimate of the probability of groups to be travelling slowly decreasing from 0.48 at a group size of 1 individual to 0.05 at a group size of 15 individuals. Multiple comparisons between years indicated a significantly greater probability of slow travel in 2019 (0.66 of groups) than in 2014 (0.12 of groups), but no other significant differences between years. Multiple comparisons of travel speed between levels of the Beaufort scale indicated no statistically significant differences, but the probability of slow travel decreased from 0.56 at level 0 to 0.21-0.25 at Beaufort levels of 2 or greater. These results suggest that it is more difficult to detect slowly-moving narwhal at higher sea states.

The model did not identify a significant effect of vessel traffic on the proportion of groups travelling slow, based on the observed data. However, statistical power was low, and an effect size of -90% or +200% would be required for sufficient power.

In summary, the 2014–2017 and 2019 integrated Bruce Head data do not support rejection of the null hypothesis that travel speed does not significantly decrease during vessel-exposure events. That is, findings do not suggest that narwhal decrease their travel speed, or “freeze”, in response to exposure to vessel traffic.

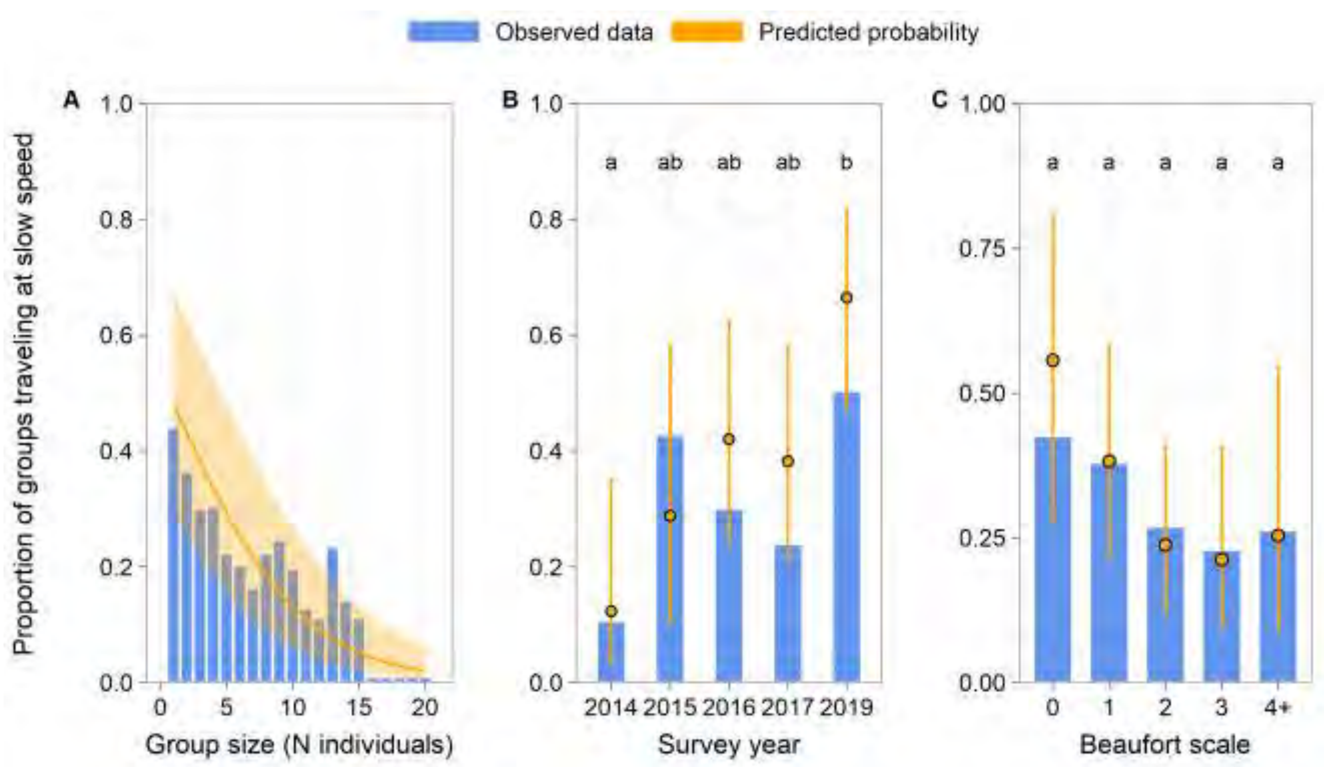


Figure 5-37: Proportion of narwhal groups observed travelling slowly (rather than at medium speed) relative to group size (panel A), survey year (panel B), and Beaufort scale (panel C).

Notes: observed data depict total proportion of groups observed travelling slowly (rather than at medium speed) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B and C), different letters indicate significant difference between groups.

5.4.6.2 Fast-travelling groups

The mixed model of group travel speed did not converge, whether as full model or as simplified model structures. Convergence was only achieved after removal of the autocorrelation term. However, since approximately 50% of periods between observations of fast-travelling groups were within one minute, the removal of temporal autocorrelation would likely result in overly narrow confidence intervals, leading to an erroneously large number of statistically significant findings.

Examination of the data indicated that fast-travelling groups were generally moving through the BSA as clumped events, since the time differences between observations of fast-moving groups were 3 minutes in 70% of the cases, and approximately 10 minutes in 80% of the cases. In comparison, the time differences between observations of slow-moving groups were 3 minutes in only 40% of the cases. That is, the observation of fast-travelling groups is highly temporally autocorrelated, and therefore related to the random effect of sampling day, and not related to the fixed effects of interest, such as vessel-related variables and observation conditions. Overall, it is concluded that the nature of the data on fast-travelling groups results in a dataset that is not adequate to test the effect of vessels on travel speed.

5.4.7 Distance from Bruce Head Shore

Based on reports suggesting that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it was predicted that narwhal moving close to shore when exposed to vessel traffic may indicate an avoidance response to a perceived threat (i.e., vessel traffic). The majority of narwhal groups observed in the BSA during 2014–2017 and 2019 sampling years were recorded close to shore (<300 m distance classification; Figure 5-38). At least 22%, 61%, 25%, 33%, and 12% of the daily groups were recorded close to shore in 2014–2017 and 2019, respectively. In 38 cases (2.8% of the 2019 data), distance from shore was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Annual averages of daily percentages of groups recorded close to shore ranged between 67% (in 2017 and 2019) and 89% (in 2015). In comparison, the annual averages of daily percentages of groups recorded farther from shore ranged between 22% (in 2015) and 50% (in 2014); the 2019 average value was 38%.

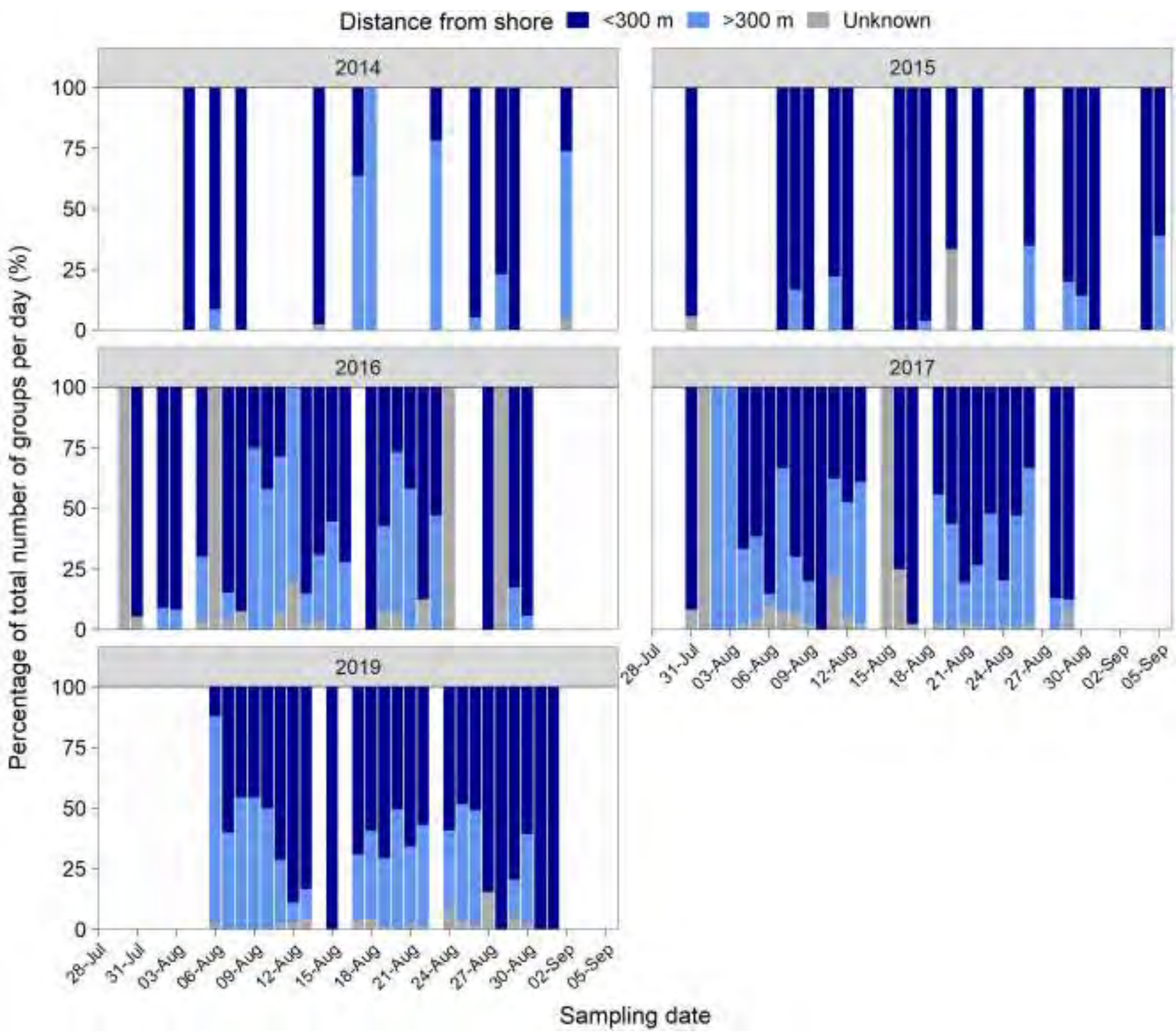


Figure 5-38: Daily distribution of narwhal distance from shore (2014 – 2017, 2019)

The distance of narwhal groups from the Bruce Head shore was analysed in relation to proximity and orientation of transiting vessels (Figure 5-39). In the combined 2014–2017 and 2019 dataset, the majority of observations of narwhal distance from Bruce Head shore were recorded when no vessels were present within 10 km of the BSA (n = 4,219), of which 34% were more than 300 m away from shore (annual percentage ranging from 23% in 2014 to 37% in 2019). Mean narwhal group size was larger for groups found closer to shore than for groups more than 300 m from shore (4.0 and 2.9 individuals, respectively; Figure 5-39).

When vessels were present within 10 km from the BSA, 665 groups with a known distance from shore were recorded. The percentage of groups found more than 300 m from shore varied with vessel direction and direction relative to the BSA. The percentage was lowest for vessels heading away from the BSA (24% for both northbound and southbound vessels), intermediate for southbound vessels heading toward the BSA (27%) and highest for northbound vessels heading toward the BSA (44%).

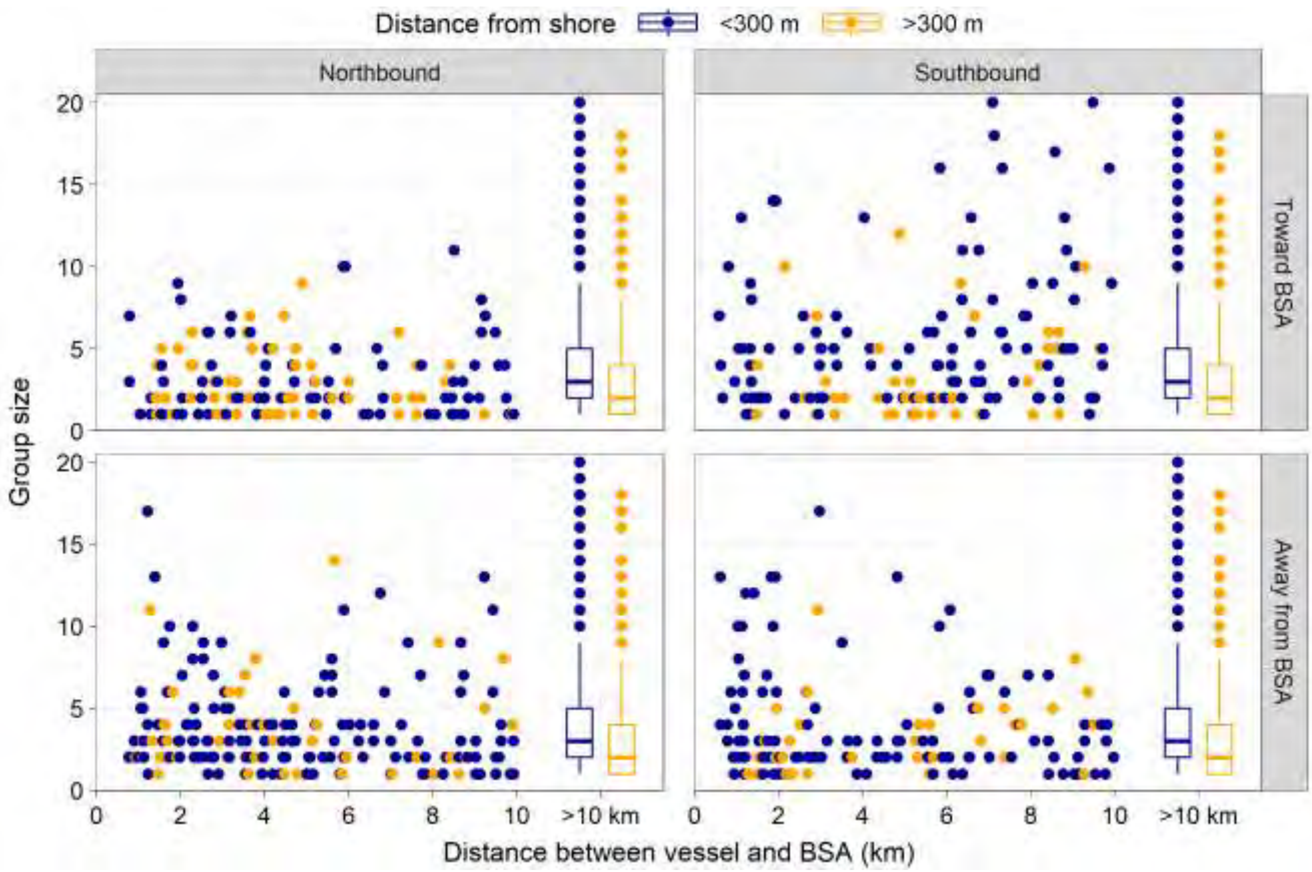


Figure 5-39: Distance from shore for narwhal groups recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

The model had a marginal (i.e., fixed-effects only) pseudo-R^2 of 0.194. That is, the model's fixed effects explained approximately 19% of the variability in observing south-travelling groups. Test statistics and coefficient estimates for the model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D. The model had sufficient power to detect some of the observed effect sizes, however effect sizes of -90% or +200% were required for sufficient power (Appendix E). The power to detect the overall effect of number of vessels within 10 km from the BSA was sufficient (>0.8) at positive effect sizes of +50% or higher, however the observed effect size was -89%, and the original model did not detect a significant effect of the number of vessels.

In the model predicting the probability of groups to be >300 m from shore, population-level estimates of the probability to observe groups >300 m from shore indicated a negative effect of group size, with predictions decreasing from 0.4 at a group size of 1 individual to 0.2 at a group size of 15 individuals (Figure 5-40). At the median size of group size in the combined data (3 individuals), the probability of observing narwhal groups >300 m from Bruce Head shore was 0.362. Multiple comparisons between years indicated a significantly lower probability of groups to be >300 m from shore in 2015 (0.06) than in 2016 to 2019 (0.28 to 0.36) but no other significant differences between years. The predicted probability to observe >300 m from shore was generally lower at Beaufort scale levels 3 and 4+ (0.13–0.16) than at levels 0 to 2 (0.27–0.36), which suggests that detection of groups farther from shore was more difficult at higher sea states, although most of the pairwise multiple comparisons between levels were not statistically significant.

The interaction between distance and vessel direction relative to BSA was statistically significant, suggesting an effect of vessel traffic on group direction (*P*=0.01). Other variables that were statistically significant predictors of the proportion of groups >300 m from shore were group size (*P*<0.001), survey year (*P*=0.008), and Beaufort scale (*P*=0.007). None of the other predictor variables in the model were statistically significant (Appendix C, Table C-17).

The significant interaction suggests that the effect of vessel distance on the presence of groups >300 m from shore depended on the vessel direction relative to the BSA. When vessels were travelling toward the BSA, population-level estimates suggested a dome-shaped relationship, with the predicted probability increasing from <0.1 at a vessel distance of 0 km (for both north- and southbound vessels) to a peak of 0.56 to 0.75 at 5-6 km (Figure 5-40). When no vessels were present within 10 km, the predicted probability of groups to be >300 m from shore was 0.36. When vessels were travelling away from the BSA, the shallow trend and the large confidence intervals around the predicted values suggested no consistent effect of vessel distance on the presence of groups >300 m from shore. In multiple comparisons between vessels at various distances (0–10 km) and when no vessels were present within 10 km, all but one comparison were not statistically significant (Table 5-10), which reflects uncertainty in the effects of vessel distance on the response variable for all vessel directions. These predicted values suggest effect sizes that are large enough to be potentially meaningful, but lack of statistical significance and large 95% confidence intervals in the predictions indicate large uncertainty in the relationship between vessel direction and distance, and group distance from shore. Multiple comparisons between 2+ vessels where the nearest vessel was at various distances from BSA and no vessels were only significantly different when the nearest southbound vessel was heading toward BSA at was at 0 km distance (*P*=0.043), but not for any other comparison (detail not shown).

In summary, the 2014–2017 and 2019 integrated Bruce Head data suggested an effect of vessel distance on group distance from shore that depended on the relative position of vessels, with the most consistent effect suggested for vessels moving toward the BSA. That is, findings suggest that narwhal may swim closer to shore as a potential anti-predator response to vessel traffic, particularly when vessels are transiting toward the BSA. Therefore, the results of the analysis support rejection of the null hypothesis that distance from Bruce Head shore does not significantly change during vessel-exposure events.

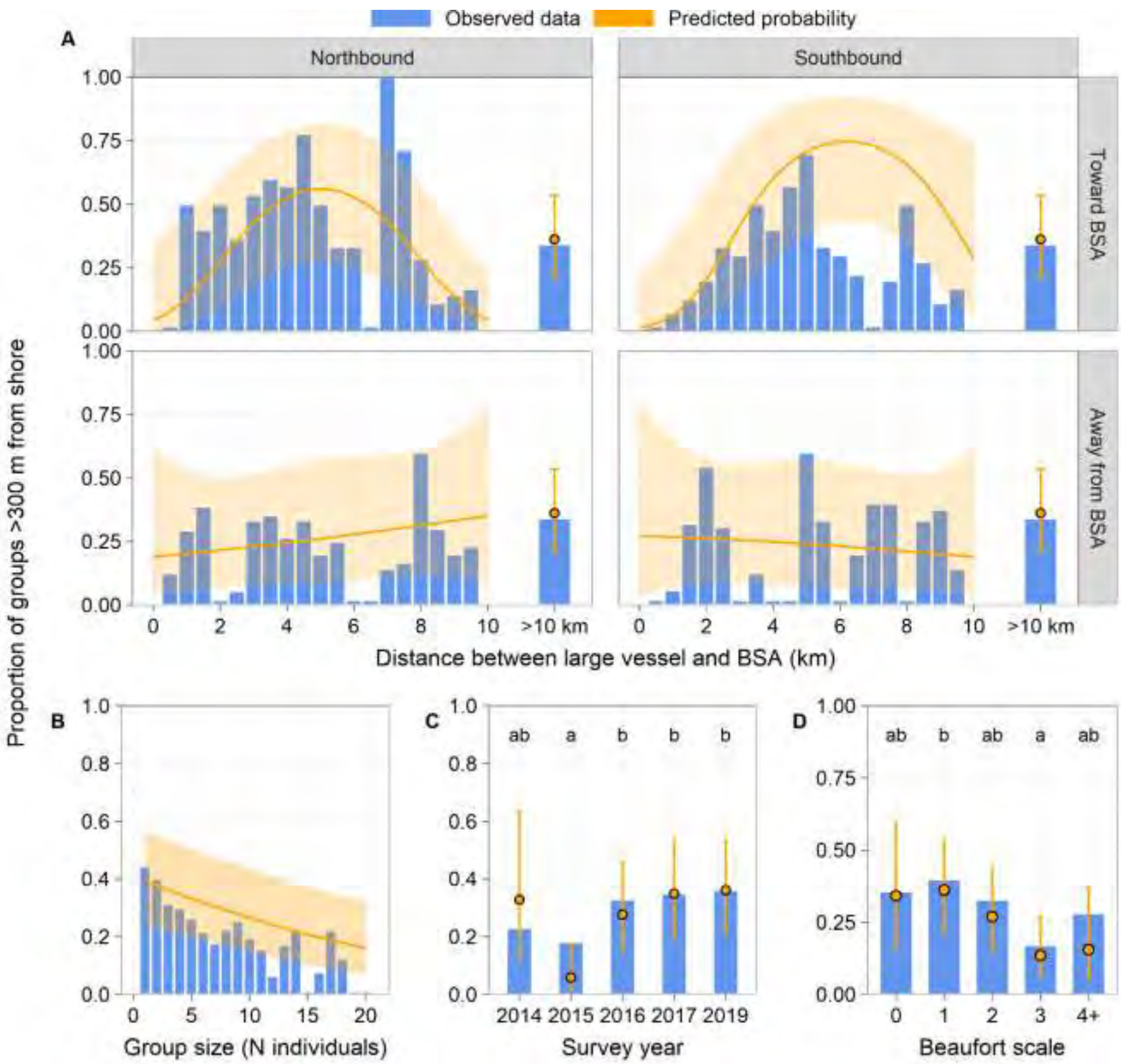


Figure 5-40: Proportion of narwhal groups observed >300 m from shore relative to distance from vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017, 2019; panel A), group size (panel B), survey year (panel C), and Beaufort scale (panel D).

Notes: observed data depict total proportion of groups observed >300 m from shore at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels C and D), different letters indicate significant difference between groups.

Table 5-10: Multiple comparisons of predictions of observing narwhal groups >300 m from shore when no vessels are within 10 km from BSA and predictions at specific distances between BSA and vessels; statistically significant values are shown in bold

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.044 (0.238)	0.189 (0.906)	0.014 (0.103)	0.272 (0.997)
1	0.132 (0.541)	0.202 (0.805)	0.064 (0.274)	0.268 (0.986)
2	0.277 (0.974)	0.216 (0.743)	0.202 (0.845)	0.262 (0.955)
3	0.427 (0.988)	0.231 (0.807)	0.414 (0.998)	0.256 (0.933)
4	0.527 (0.722)	0.246 (0.895)	0.60 (0.539)	0.249 (0.930)
5	0.560 (0.592)	0.262 (0.946)	0.707 (0.160)	0.241 (0.922)
6	0.529 (0.740)	0.278 (0.972)	0.746 (0.071)	0.232 (0.894)
7	0.432 (0.985)	0.296 (0.986)	0.730 (0.068)	0.222 (0.833)
8	0.283 (0.967)	0.314 (0.996)	0.655 (0.243)	0.212 (0.764)
9	0.136 (0.275)	0.332 (1.000)	0.502 (0.933)	0.201 (0.794)
10	**0.046 (0.047)**	0.351 (1.000)	0.289 (0.998)	0.190 (0.898)

5.5 General Observations

Narwhal were frequently observed south of the SSA in the general vicinity of Koluktoo Bay and the entrance to Assomption Harbour. Similar distribution of narwhal in this area has been reported during aerial surveys (Thomas et al. 2015, 2016; Golder 2018b; Golder 2020b) affirming the importance Koluktoo Bay may serve as a refuge for narwhal during the shipping season.

The majority of narwhal recorded in the BSA over the five years of data collection were engaged in travelling behaviour. Other behaviours observed in the BSA included nursing, rubbing, tusking, foraging, and mating. In all years, narwhal calves were commonly observed, with observations of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions) and 2017 (two occasions). On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these qualitative observations lend further support to the hypothesis that this part of Milne Inlet is important for calf rearing.

In 2016, narwhal were observed foraging on arctic cod near the Bruce Head shore on several days in early August (Smith et al. 2017). The foraging groups included mother-calf pairs, although these were not commonly observed feeding.

In 2016 and 2017, despite increased shipping traffic in these years, narwhal were regularly observed in the SSA and adjacent areas of Milne Inlet throughout the survey period (Smith et al. 2016; Golder 2018).
Ad lib observations made by the observers suggested that the response of narwhals to ore carrier traffic was

variable, ranging from ‘no obvious response’ in which animals remained in close proximity to ore carriers as they transited through the SSA, to temporary and localized displacement and related changes in behaviour. However, no overall decrease in the abundance of narwhal in the area was observed.

During each year of this shore-based study, narwhal were observed to respond to shooting events by diving and increasing their swim speed. Despite repeatedly being shot at from the same location (i.e., the hunting camp below the observation platform), narwhal were always observed to return to the area at the base of Bruce Head, though the time until they returned was variable.

5.5.1 Other Marine Mammals

On 18 August 2019, a pod of eight orca whales (*Orcinus orca*) were observed travelling south through the SSA (substrata A1, A2, A3, B2, C3, D2, and E2). Beluga whale (*Delphinapterus leucas*) were recorded within the SSA on two separate occasions – five individuals were recorded in the SSA on 9 August 2019, and a single individual was recorded within the BSA on 17 August 2019. A bowhead whale (*Balaena mysticetes*) was also recorded in the SSA on two separate occasions – on 10 August and 12 August 2019.

Table 5-11: Other cetacean species observed within the SSA during the 2019 Bruce Head program

Species	Date of Record	Number of Individuals
Orca whale	2019-08-18	8
Beluga whale	2019-08-09	5
	2019-08-17	1
Bowhead whale	2019-08-10	1
	2019-08-12	1

6.0 DISCUSSION

6.1 Relative Abundance and Distribution

Overall, the relative abundance of narwhal (total number narwhal corrected for effort) in 2019 was shown to be comparable to that reported in previous survey years, including from baseline monitoring conducted in 2014, prior to the start of iron ore shipping operations in the RSA. These results suggest the current level of shipping in the RSA has not resulted in any large-scale displacement or avoidance behaviour by narwhal in the SSA, nor abandonment of this traditional part of their summering ground. These findings are consistent with results from Baffinland's other narwhal monitoring programs demonstrating that the Bruce Head area continues to support high narwhal concentrations and proportionately higher habitat use by narwhal compared to other areas in the RSA (Elliott et al. 2015; Thomas et al. 2015; Golder 2020a; Golder 2020b).

The statistical model of RAD data included all interactions between three vessel-related variables: 1) vessel distance from a given substratum; 2) whether the vessel was heading toward or away from a substratum; and 3) whether the vessel was north- or southbound. The three-way interaction was significant, which means that at least one of the two-way interactions (e.g., between distance from vessel and whether the vessel was moving toward or away from the substratum) changes across the third independent variable (e.g., whether the vessel was north- or southbound). The model predicted reduced counts of narwhal when a northbound vessel was near the substrata (≤4 km) and a peak in narwhal counts when vessels were 6–8 km from the substrata. In contrast, for southbound vessels, increased counts were predicted when vessels were near (although for a southbound vessel heading away from the substrata, two peaks were estimated – one when the vessel was close and another when the vessel was at 6-8 km).

The results of the combined 2014–2017 and 2019 analysis are mostly similar to the result of the analysis of the combined 2014-2017 dataset (Golder 2019), with the main difference being that in the current analysis, the relative direction of the vessel (i.e., whether it was heading toward or away from substrata) was found to be a significant predictor. While the analysis of the 2014-2016 dataset (Smith et al. 2017) found that narwhal counts were significantly different when northbound vessels were heading away from a substratum than in all other scenarios, this was not the case in the current analysis. This change likely stems from the combination of a larger dataset (which includes two more years of collected data) and differences in utilized model structures. Of note, Smith et al. (2017) used categorical variables to describe vessel presence whereas the model presented here used vessel distance as a continuous variable to assess vessel effects on narwhal. In addition, the model presented here also included interactions between vessel distance, whether the vessel was heading away or toward the substratum centroid, and whether the vessel was northbound or southbound, whereas the model in Smith et al. (2017) contained only main effects. The interactions allowed assessing whether narwhal responses differed at different vessel traffic scenarios.

It is possible that the difference in narwhal response to north- and southbound vessels is due to the difference in vessel noise propagation, combined with the spatial distribution of narwhal. Specifically, the noise output of northbound vessels propagates without an impediment throughout the opening of Koluktoo Bay and the southern strata of the SSA, where the majority of narwhal are usually located. Conversely, the noise of a southbound vessel north of Poirier Island is impeded by the Bruce Head peninsula, potentially resulting in a different response of narwhal in the southern strata and Koluktoo Bay.

Once a northbound vessel passed the SSA and started heading away from it, narwhal abundance gradually increased until the vessel was 6 to 8 km away. The same pattern was observed for a southbound vessel moving away from the substrata. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial displacement. The pattern in narwhal abundance relative to southbound vessel distance is less consistent. When southbound vessels were in close proximity to the substrata, the model predicted a strong increase in narwhal counts, which was not evident from the data. It is possible that the spatial extent of the effect of vessels does not cover the full 10 km modeled, as was found in the analysis of dive and movement behaviour of narwhal equipped with GPS and dive tags (Golder 2020a). In this case, it is likely that the model overestimated narwhal counts in the vicinity of vessels, to better fit counts farther from the vessel (where the effect from vessel traffic is likely smaller).

6.2 Group Composition and Behaviour

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing narwhal behavioural responses to a potential perceived threat (i.e. vessel traffic). For example, narwhal are known to alter their spatial use patterns in the presence of predators by moving slowly, travelling close to shore, and in tight groups at the surface (Campbell et al. 1988; Cosens and Dueck 1991; Laidre et al. 2006; Breed et al. 2017). In one report detailing an attack by killer whales, it was documented that once the attack commenced, narwhal further altered their spatial use by dispersing widely (approximately doubling their normal spatial distribution), beaching themselves in sandy areas, and quickly shifting their distribution away from the attack site (Laidre et al. 2006). In drawing from accounts of predator-induced behavioural responses by narwhal, the following response variables were evaluated for narwhal in the BSA as a function of vessel exposure, assuming narwhal respond to vessel traffic in a similar manner as they do with predators.

6.2.1 Group Size

As none of the effects of shipping on narwhal group size were shown to be statistically significant, the results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure. However, the model only had sufficient power to detect an effect size of -35% or +45% relative to when no vessels were present, whereas observed effect sizes only ranged between -11% and +27%.

6.2.2 Group Composition

Depending on the composition of individuals that make up a group, narwhal groups may possess different strategies and/or capabilities for temporarily avoiding the potential disturbance of a transiting vessel. For example, adult groups may perceive vessel traffic and associated noise as a potential threat and attempt to move away from it by changing course or altering travel/dive behaviour, while mother/offspring groups may not be able to respond in a similar manner given physiological limitations of the calf (i.e., slower swimming speed, reduced dive capability; Marcoux et al. 2009).

Despite steadily increasing vessel traffic through Milne Inlet since 2014, narwhal groups with calves/yearlings have been present in the BSA throughout the five years of data collection. Similar to previous years, both calves and yearlings were observed during most sampling days, with only two days (15 and 28 August 2019) with no calves or yearlings recorded. In 2019, the daily proportion of calves (relative to total narwhal counts) ranged between 0% (on 15 and 28 August) and 19% (on 9 August 2019). In previous years, mean annual percentage of calves ranged between 0% (in all years) and 23-50% (23% in 2014 and 50% in 2017). Annual mean values in 2019 (11.2%) were higher than all previously estimated annual means (2014=10.7%, 2016=9.7%, 2017=7.7%), except for 2015 when a mean annual value of 14% was recorded. The mean proportion of calves recorded in 2019 suggests that calving success at Bruce Head is still occurring at a similar rate as that during the pre-shipping period, despite year-over-year increases in shipping in the RSA. However, the model found that the odds of presence of calves and/or yearlings depended on the combination of vessel distance, vessel direction relative to the BSA, and vessel direction within Milne Inlet. That is, while the odds of presence of calves and/or yearlings did not change between years despite an increase in vessel traffic, the odds of observing groups possessing calves and/or yearlings was shown to increase during close vessel encounters. This finding may be a function of those groups possessing calves and/or yearlings being less able to dive, however, thus inflating the odds of observing such groups while groups without calves and/or yearlings may be more able to leave the area (i.e. dive) in response to vessel exposure.

Overall, the results suggest the current level of shipping in the RSA has not resulted in any discernable changes in presence of offspring over the five years of data collection, nor any evidence of large-scale displacement or avoidance behaviour by mother-calf pairs in the SSA, nor abandonment of mother-calf pairs for this part of their traditional calving grounds.

6.2.3 Group Spread

Consistent with observations from previous years, narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. Narwhal group spread did not significantly change during vessel-exposure events. However, loosely spread groups were less commonly observed when vessels headed away from the BSA (32% for northbound vessels and 30% for southbound vessels) than when vessels headed toward the BSA (38% for northbound vessels and 32% for southbound vessels). Based on reports suggesting that narwhal alter their spatial use patterns in the presence of a perceived threat (i.e., killers whales) by associating in tighter groups (Laidre et al. 2006), these results do not indicate that such an anti-predator response is strongly elicited when narwhal are exposed to vessel traffic as individuals neither congregated into tighter groups nor dispersed widely. That is, model results suggested that vessel traffic may elicit a slight, though non-significant, anti-predator response in narwhal.

6.2.4 Group Formation

Consistent with observations from previous years, narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. Despite none of the shipping-related variables being statistically significant, a possible but uncertain effect of vessel distance on narwhal group formation was evident that depended on vessel direction, with the most consistent effect suggested for southbound vessels moving away from the BSA. Of note, the lowest percentage of narwhal groups in non-parallel formation was recorded during the passage of southbound vessels transiting away from BSA (27%). As knowledge regarding the context and function (if any) of narwhal aggregations is generally incomplete (Marcoux et al. 2009), further monitoring of narwhal group formation is warranted to better understand whether a given formation is indicative of a potential response to a perceived threat (i.e. a transiting vessel).

6.2.5 Group Direction

Consistent with observations from previous years, narwhal groups were predominantly observed travelling south through the BSA in 2019 and tended to travel south in large groups and north in relatively smaller groups. Travel direction of narwhal groups was significantly affected by exposure to vessel traffic. Of note, south-travelling groups were observed less frequently (38% of the time) when southbound vessels transited away from the BSA. This finding may suggest that some narwhal groups tend to avoid travelling south (i.e., toward Milne Port) in the wake of vessels also transiting south. A similar trend was observed by the very low proportion of narwhal groups travelling north in the wake of vessels also transiting north. These findings together suggest that narwhal groups may experience some level of avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid “following” vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels.

6.2.6 Travel Speed

Similar to the anti-predator response elicited in narwhal when interacting with killer whales (i.e., their top predator; Breed et al. 2017), a change in swimming speed in the presence of vessel traffic may signify avoidance of a perceived threat by narwhal (Williams et al. 2002). Given that the majority of narwhal groups were observed travelling at a medium speed, regardless of large vessel presence/absence, and did not decrease their travel speed in response to vessel exposure, vessel traffic was not found to elicit a “freeze response” by narwhal in the study area. This finding is consistent with findings from the 2017-2018 Integrated Narwhal Tagging Study which indicated that narwhal do not alter their travel speed in the presence of transiting vessels (Golder 2020a). As the nature of the dataset on fast-travelling groups was not adequate to test the effect of vessels on increased travel speed by narwhal, it could not be tested whether animals exhibited a strong avoidance response to vessel traffic.

6.2.7 Distance from the Bruce Head Shore

The distance that narwhal groups were observed from shore was shown to change with distance from a vessel and depended on the relative position of vessels, with the most consistent effect suggested for vessels moving toward the BSA. Of note, narwhal were observed swimming closer to shore in response to vessels approaching the BSA. As reports suggest that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it is conceivable that narwhal moving closer to shore when exposed to vessel traffic indicates an avoidance response to a perceived threat (i.e., vessel traffic). However, consistent with observations from previous years, narwhal groups were regularly observed at a distance <300 m of the Bruce Head shore compared to groups >300 m offshore under both vessel presence and vessel absence scenarios. Monitoring of narwhal distance from shore is therefore an appropriate metric to assess habitat use and whether the proportion of inshore vs. offshore narwhal groups is dependent on anthropogenic activity.

7.0 SUMMARY OF KEY FINDINGS

Relative Abundance and Distribution

- The overall relative abundance of narwhal in the SSA, inferred from sighting rate (no. of narwhal per hour - corrected for effort), has remained relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. **Narwhal numbers in the SSA were shown to be comparable to baseline levels documented during the 2014 Bruce Head Monitoring Program, which took place prior to the start of iron ore shipping, noting however that some level of shipping activity still occurred through the SSA during 2014 (e.g., five Project support vessels and 13 non-Project-related vessels).** These findings are consistent with results from Baffinland's other narwhal monitoring programs demonstrating that the Bruce Head area continues to support high narwhal densities and proportionately higher habitat use by narwhal compared to other areas in the broader RSA (Elliott et al. 2015; Thomas et al. 2015; Golder 2020a; Golder 2020b).
- Within each study year, a likely but uncertain effect of vessel exposure on narwhal relative abundance in the SSA was observed. Specifically, vessel exposure was shown to result in a significant decrease in narwhal sightings in the SSA compared to when no vessels were present, but only when narwhal were exposed to vessels travelling north and away from the study area, and only at close exposure distances of 2-3 km. **These results suggest that the relative abundance of narwhal is influenced by vessel traffic at close distances, although the exact spatial extent of this effect could not be determined due to high data variability.**

Group Composition and Behaviour

- Group Size: None of the effects of shipping (distance from vessel, vessel direction, vessel orientation relative to the Behavioural Study Area or BSA) on narwhal group size were shown to be statistically significant ($P>0.2$ for all effects), however statistical power was only sufficient to detect effect sizes of -35% or +45%, whereas observed effect sizes were not as pronounced. **These results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure.**
- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the five sampling years. The daily proportion of calves and/or yearlings recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2019 (annual mean of 11.2%) than all previous years (2014=10.7%, 2016=9.7%, 2017=7.7%), with the exception of 2015 (14%). This suggests that calving success at Bruce Head in 2019 was consistent with pre-shipping levels, despite year-over-year increases in shipping in the BSA.
  - Vessel traffic was shown to have a significant effect on group composition relative to the probability of calf/yearling presence (i.e., a significant interaction was observed between 'vessel distance', 'vessel direction' and 'vessel orientation relative to BSA'). Results suggest that the proportion of groups with calves/yearlings was similar between all four vessel traffic scenarios (i.e., vessel transiting toward/away BSA, vessel transiting southbound/northbound), but generally increased during close vessel encounters. This finding may suggest that groups with calves/yearlings may be less inclined to maneuver out of the way of transiting vessels at close distances, though it is unclear whether this effect was significant. Further assessment of the relative proportion of strictly mature groups (i.e. groups possessing no calves or yearlings) during close vessel encounters should be carried out in future analyses for comparison.

- **Collectively, these results suggest that narwhal group composition did not significantly change between study years despite an increase in shipping activity during this period, but the proportion of groups with calves/yearlings was generally higher during close vessel encounters.**

- Group Spread: Narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. In general, group spread did not significantly change during vessel-exposure events. However, loosely spread groups were less common when vessels headed away from the BSA (32% for northbound vessels and 30% for southbound vessels) than when vessels were heading toward the BSA (38% for northbound vessels and 32% for southbound vessels). **These results suggest that narwhal group spread did not significantly change during vessel exposure events.**
- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. A possible but uncertain effect of vessel distance on narwhal group formation was evident that depended on vessel direction, with the most consistent effect suggested for southbound vessels moving away from the BSA. However, none of the shipping-related variables were statistically significant due to insufficient statistical power. **These results suggest that narwhal group formation did not significantly change in the BSA during vessel exposure events.**
- Group Direction: Vessel traffic was shown to have a significant effect on travel of narwhal groups in the BSA (i.e., a significant interaction was observed between 'vessel distance', 'vessel direction' and 'vessel orientation relative to BSA' although the effect on travel direction was shown to be variable). Narwhal groups were predominantly observed traveling south through the BSA. Southbound travel was least common when southbound vessels were headed away from the BSA, and most common when northbound vessels were headed away from the BSA. **These findings suggest that narwhal groups may experience some level of avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid "following" vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels.**
- Travel Speed: The majority of the observed narwhal groups travelled at a medium speed, regardless of vessel exposure conditions. A lack of statistical significance of any of the vessel-related variables suggests that vessel traffic did not have an effect on narwhal groups decreasing their travel speed. The nature of the data for fast-travelling groups was not adequate to test for the effect of vessel exposure on increased travel speed in the BSA. **These results suggest that narwhal did not decrease their travel speed or demonstrate a 'freeze' response during vessel exposure events as they've shown to do during encounters with other perceived threats (i.e. killer whales).**
- Distance from Bruce Head Shore: Narwhal groups were observed more often within 300 m of the Bruce Head shore under both vessel presence and vessel absence scenarios. Offshore groups (>300 m) were detected less frequently with increasing Beaufort scale values, suggesting a decreased detection ability at distance with deteriorating sea state. Furthermore, vessel traffic was shown to result in a significant decrease in 'distance from shore' (i.e., significant interaction was between 'vessel distance', 'vessel direction' and 'vessel orientation). This effect appeared to be largely attributed to vessel traffic moving toward the BSA. **The results suggest that narwhal swim closer to shore when in close proximity to vessels moving toward the BSA.**

Overall, results from this five-year shore-based monitoring study support impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that ship noise effects on narwhal will be limited to localized avoidance behaviour, consistent with low to moderate severity responses (Southall et al. 2007; Finneran et al. 2017). No evidence was observed of large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a non-significant effect used in the FEIS).

8.0 RECOMMENDATIONS

The following recommendations should be considered with respect to future shore-based monitoring programs at Bruce Head, in addition to feedback received during end of season interviews with Inuit participants (APPENDIX F):

- Data collection:
  - It is recommended to explore validating narwhal sightings data by imagery and/or video collected simultaneously via an UAV throughout the SSA. This may provide a means to verify RAD counts and may allow for correction of observation bias under conditions of low visibility and/or increased distance from the observation platform. In addition, UAV footage may be helpful for filling in missing information on narwhal behaviour and group composition in the BSA, where observers are not able to record certain aspects of group behaviour due to reduced sightability.
  - It is recommended to explore correlating narwhal sightings and UAV data with acoustic data collected in the vicinity of Bruce Head via Autonomous Multichannel Acoustic Recorders (AMARs). The objective of this component is to assess group-specific vocal behaviour relative to shipping activities. Special attention should be paid to mother-calf pairs with the objective of assessing mother-calf contact calls relative to shipping activities.
- Analysis:
  - As more data are collected on narwhal group composition, behaviour, and RAD when in close proximity to vessels, it is recommended that the 10 km exposure zone be further restricted in order to better estimate vessel effects on narwhal at close distances. Although the current exposure zone distance was restricted in 2019 from previous years (i.e., 15 km to 10 km), potential effects at close proximity (≤3 km) to vessels are not always captured when accounting for trends at further distances, warranting further restriction of the 10 km exposure zone. The further restriction of the exposure zone distance is likely to increase statistical power to detect the effects of shipping on narwhal behaviour and group composition.
  - In the analysis of behavioural data, results suggested that hunting was an effect, rather than a cause of the observed outcome. For example, group size was largest immediately after shots were fired, slowly declining over time. It is considered likely that hunting occurred because the hunters noticed the larger narwhal group sizes in the study area and thus commenced hunting. Therefore, the inclusion of hunting as a predictor in these models may not be beneficial. This merits further discussion with the MEWG on whether to retain hunting as a predictor in the model moving forward.
  - Based on the results obtained over the five years of data collection at Bruce Head, it is recommended that the response variable, travel speed, not be carried forward in future analyses of narwhal response to vessel traffic given the logistical challenges associated with adequately quantifying the parameters. UAV data obtained during the 2020 field program will be used to further evaluate additional behavioral response variables that may be carried forward in future analyses.
  - When assessing the potential for groups of different composition to avoid a transiting vessel, it is recommended that future analyses assess the response of mature groups relative to groups possessing immature animals. This would allow for evaluating whether groups of different composition show different response strategies based on their potential to actively avoid or maneuver away from vessels (i.e., immatures may be less capable to actively avoid vessels).

- For the RAD analysis, it is recommended that future models focus on analysis of animal density in the SSA in order to account for the variable sizes of the different substrata. This methodology differs from how the analysis has been conducted in previous years, in which narwhal counts were modeled exclusively (Smith et al. 2016; Golder 2019). By accounting for the different sampling areas of each substratum, changes to the relative density of whales may be analyzed, resulting in a more biologically meaningful indicator of population health than simply changes to observed counts.

- Mitigation measures:
  - Mitigation measures currently established to minimize vessel-related impacts to marine mammals along the Northern Shipping Route include a maximum 9 knots speed limit imposed for Project-related vessels throughout the RSA. According to satellite and shore-based AIS data, the majority of ore carrier travel speeds recorded in Milne Inlet were in compliance with speed restrictions. It is therefore recommended that the 9 knot speed limit be respected by all other non-Project-related vessels operating in the RSA where possible (noting this would need to be implemented by the applicable regulatory authorities), as reduced vessel speeds have proven to be effective in reducing the risk of noise exposure and vessel strikes on marine mammals.

9.0 CLOSURE

We trust the information contained in this report is sufficient for your present needs. Should you have any additional questions regarding the project, please do not hesitate to contact the undersigned.

Golder Associates Ltd.

Ainsley Allen, MSc. RPBio
Marine Biologist

Sima Usvyatsov, PhD
Biological Scientist

Phil Rouget, MSc, RPBio
Senior Marine Biologist

Mitch Firman, BSc
Wildlife Ecologist

Reviewed by:

Bart DeFreitas, MSc, RPBio, PMP
Associate, Senior Biologist, Project Manager

AA/SU/PR/MF/BDF/syd

\\golder.gds\gal\burnaby\final\2016\3 proj\1663724 baff_marinemammalsurvey_ont\1663724-199-r-rev0-23000\1663724-199-r-rev0-23000-bruce head 03sep_20.docx

10.0 REFERENCES

Arveson, R.T., and D.J. Vendittis. 2000. Radiated noise characteristics of a modern cargo ship. Acoustical Society of America 107(1): 118-129.

Bluhm, B.A. and R. Gradinger. 2008. Regional variability in food availability for Arctic marine mammals. Ecological Applications 18: S77‑S96.

Born, E.W. 1986. Observations of narwhals (Monodon monoceros) in the Thule area (NW Greenland). August 1984. Rep. Int. Whaling Comm. 36: 387-392.

Breed, G.A., C.J.D. Matthews, M. Marcoux, J.W. Higdon, B. LeBlanc, S.D. Petersen, J. Orr, N.R. Reinhart and S. Ferguson. 2017. Sustained disruption of narwhal habitat use and behaviour in the presence of Arctic killer whales. PNAS. 114(10): 2628-2633.

Brooks M.E., K. Kristensen, K.J. van Benthem, A. Magnusson, C.W. Berg, A. Nielsen, H.J. Skaug, M. Maechler, and B.M. Bolker. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal. 9(2): 378-400.

Campbell, R.R., D.B. Yurick and N.B. Snow. 1988. Predation on narwhals, *Monodon monoceros*, by killer whales, *Orcinus orca*, in the eastern Canadian Arctic. Can. Field-Nat. 102: 689-696.

Charry, B. 2018. The distribution of narwhal (*Monodon monoceros*) males, females, and newborns in the Canadian Arctic Archipelago [MSc thesis]. Montreal: McGill University. 101 p.

Cosens, S.E. and L.P. Dueck. 1988. Responses of migrating narwhal and beluga to icebreaker traffic at the Admiralty Inlet ice-edge, N.W.T. in 1986. pp 39-54 *In* W.M. Sackinger and M.O. Jeffries (eds.). Port and ocean engineering under Arctic conditions, Vol. 2. University of Alaska Fairbanks, Fairbanks, AK.

Cosens, S.E. and L.P. Dueck. 1991. Group size and activity patterns of belugas (Delphinapterus leucas) and narwhals (*Monodon monoceros*) during spring migration in Lancaster Sound. Canadian Journal of Fisheries and Aquatic Sciences. 69: 1630-1635.

COSEWIC. 2004. COSEWIC assessment and update status report on the narwhal *Monodon monoceros* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 50 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Davis, R.W. 2014. A review of the multi-level adaptations for maximizing dive duration in marine mammals: from biochemistry to behaviour. Journal of Comparative Physiology. 184(1): 23‑53.

Dietz, R. and M.R. Heide-Jorgensen. 1995. Movements and swimming speed of narwhals, *Monodon monoceros*, equipped with satellite transmitters in Melville Bay, northwest Greenland. Canadian Journal of Zoology, 73: 2106-2119.

Dietz, R., M.P. Heide-Jørgensen, P. Richard, and M. Acquarone. 2001. Summer and fall movements of Narwhal (*Monodon monoceros*) from Northeastern Baffin Island towards Northern Davis Strait. Arctic. 54:244-261.

Doniol-Valcroze, T., J.F. Gosselin, D. Pike, J. Lawson, N. Asselin, K. Hedges and S. Ferguson. 2015. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013. DFO Canadian Science Advisory Secretariat Science Advisory Report 2015/060. v + 36 pp.

Ellison, W., B. Southall, C. Clark and A. Frankel. 2012. A new context-based approach to assess marine mammal behavioural responses to anthropogenic sounds. Conservation Biology 26(1): 21-28.

Finley, K.J. and E.J. Gibb. 1982. Summer diet of the narwhal (*Monodon Monoceros*) in Pond Inlet, northern Baffin Island. Canadian Journal of Zoology. 60: 3353-3363

Finley, K.J., G.W. Miller, R.A. Davis and C.R. Greene. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhal, *Monodon monoceros*, to ice-breaking ships in the Canadian high arctic. Canadian Journal of Fisheries and Aquatic Science. 224: 97-117.

Finneran, J.J. and A.K. Jenkins. 2012. Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis. SPAWAR Systems Center Pacific, San Diego, California.

Finneran, J., E. Henderson, D. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). June 2017. 194 pp.

Fisheries and Oceans Canada (DFO). 2011. Advice regarding the genetic structure of Canadian narwhal (*Monodon monoceros*). DFO Canadian Science Advisory Secretariat Science Advisory Report 2011/021. 5 p.

Ford, J.K.B. and H.D. Fisher. 1978. Underwater acoustic signals of the narwhal (*Monodon monoceros*). Canadian Journal of Zoology. 56: 552-560.

Frouin-Mouy, H., E.E. Maxner, M.E. Austin, and S.B. Martin. 2019. Baffinland Iron Mines Corporation – Mary River Project. 2018 Passive Acoustic Monitoring Program. Document 10720. Version 3.0. Technical Report by Jasco Applied Sciences for Golder Associates Ltd.

Frouin-Mouy, H., C.C. Wilson, K.A. Kowarski, and M.E. Austin. 2020. Baffinland Iron Mines Corporation – Mary River Project. 2019 Passive Acoustic Monitoring Program – Draft Report. Document 02007. Version 2.2. Technical Report by Jasco Applied Sciences for Golder Associates Ltd.

Furgal, C., and R. Laing. 2012. A synthesis and critical review of the Traditional Ecological Knowledge literature on narwhal (*Monodon monoceros*) in the eastern Canadian Arctic. DFO Canadian Science Advisory Secretariat Science Advisory Report 2011/131 iv + 47 p.

Garde, E., S. H. Hansen, S. Ditlevsen, K. B.Tvermosegaard, J. Hansen, K. C. Harding and M. P. Heide-Jørgensen. 2015. Life history parameters of narwhals (*Monodon monoceros*) from Greenland. Journal of Mammalogy. 96(4): 866-879.

Golder Associates Ltd. (Golder). 2020a. 2017 – 2018 Integrated narwhal tagging study. Technical Data Report. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario.

Golder Associates Ltd. (Golder). 2020b. 2019 Marine mammal aerial survey. Report No. 1663724-XX-R-RevB. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 118 p. + appendices.

Golder Associates Ltd. (Golder). 2019. Bruce Head shore-based monitoring program. Final 2014-2017 Integrated Report No. 1663724-081-R-Rev0. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 119 p. + appendices.

Golder Associates Ltd. (Golder). 2018a. 2017 Bruce Head shore-based monitoring program. Final Golder Report No. 1663724-041-R-Rev0. Prepared by Golder Associates Ltd., Victoria, BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Hauser, D.D.W, K.L. Laidre and H.L. Stern. 2018. Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route. Proceedings of the National Academy of Science of the USA 115: 7617–7622.

Heide-Jørgensen, M.P., R. Dietz, K.L. Laidre and P. Richard. 2002. Autumn movements, home ranges, and winter density of narwhals (*Monodon monoceros*) tagged in Tremblay Sound, Baffin Island. Polar Biology. 25: 331-341.

Heide-Jørgensen M.P. and R. Dietz. 1995. Some characteristics of narwhal, *Monodon monoceros*, diving behaviour in Baffin Bay. Canadian Journal of Zoology. 73: 2120–2132.

Heide-Jørgensen, M.P., N. Hammeken, R. Dietz, J. Orr and P.R. Richard. 2001. Surfacing times and dive rates for narwhals (*Monodon monoceros*) and belugas (*Delphinapterus leucas*). Arctic. 54: 284–298.

Heide-Jørgensen, M.P., R.G. Hansen, K. Westdal, R.R. Reeves and A. Mosbech. 2013a. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments? Biological Conservation. 158: 50-54.

Heide-Jørgensen, M.P., K.L. Laidre, N.H. Nielsen, R.G. Hansen and A. Rostad. 2013b. Winter and spring diving behaviour of bowhead whales relative to prey. Animal Biotelemetry. 1:15.

Heide-Jørgensen, M.P., K.L. Laidre, Ø. Wiig, M.V. Jensen, L. Dueck, L.D. Maiers, H.C. Schmidt and R.C. Hobbs. 2003. From Greenland to Canada in ten days: Tracks of bowhead whales, *Balaena mysticetus*, across Baffin Bay. Arctic. 56(1): 21-31.

Holt, M.M., D.P. Noren and C.K. Emmons. 2013. An investigation of sound use and behaviour in a killer whale (*Orcinus orca*) population to inform passive acoustic monitoring studies. Marine Mammal Science, 29(2): E193-E202.Huntington, H.P. 2009. A preliminary assessment of threats to arctic marine mammals and their conservation in the coming decades. Marine Policy. 33(1): 77-82.

Innes, S., M.P. Heide-Jørgensen, J.L. Laake, K.L. Laidre, H.J. Cleator, P. Richard and R.E.A. Stewart. 2002. Surveys of belugas and narwhals in the Canadian High Arctic in 1996. NAMMCO Sci. Publication. 4: 169–190.

Jason Prno Consulting Services Ltd. (JPCS). 2017. Results of Community Workshops Conducted for Baffinland Iron Mines Corporation's Phase 2 Proposal. Report prepared for Baffinland Iron Mines Corporation. January 2017.

Kingsley, M.C.S., H.J. Cleator and M.A. Ramsay. 1994. Summer distribution and movements of narwhals (*Monodon monoceros*) in Eclipse Sound and adjacent waters, North Baffin Island, N.W.T. Meddelelser om Grønland, Bioscience. 39: 163–174.

Koblitz, J.S., P. Stilz, M.H. Rasmussen and K.L. Laidre. 2016. Highly directional sonar beam of narwhals (*Monodon monoceros*) measured with a vertical 16 hydrophone array. PLoS ONE 11(11): e0162069. 17 pp.

Koski, W.R. and R.A. Davis. 1994. Distribution and numbers of narwhal (*Monodon monoceros*) in Baffin Bay and Davis Strait. Medd Grøn Biosci. 39:15–40.

Laidre, K.L. and M.P. Heide-Jørgensen. 2005. Winter feeding intensity of narwhal (*Monodon monoceros*). Marine Mammal Science. 21(1): 45-57.

Laidre, K.L., M.P. Heide-Jørgensen and R. Dietz. 2002. Diving behaviour of narwhals (*Monodon monoceros*) at two coastal localities in the Canadian High Arctic. Canadian Journal of Zoology. 80: 624–635.

Laidre, K.L., M.P. Heide-Jørgensen, R. Dietz, R.C. Hobbs and O.A. Jørgensen. 2003. Deep-diving by narwhals, *Monodon monoceros*: differences in foraging behaviour between wintering areas? Marine Ecology Progress Series. 261: 269–281.

Laidre, K.L., M.P. Heide-Jørgensen, M.L. Logsdon, R.C. Hobbs, P. Heagerty, R. Dietz, O.A. Jørgensen and M.A. Trebel. 2004. Seasonal narwhal habitat associations in the high Arctic. Marine Biology. 145: 821–831.

Laidre, K.L., M.P. Heide-Jørgensen and J. Orr. 2006. Reactions of narwhals, *Monodon monoceros*, to killer whale, *Orcinus orca*, attacks in the eastern Canadian Arctic. Canadian Field-Naturalist. 120: 457-465.

Langsrud Ø. 2003. ANOVA for unbalanced data: use type II instead of type III sums of squares. Statistics and Computing. 13 (2): 163-167.

Length, R. 2020. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.4.5.009003. https://github.com/rvlenth/emmeans

Lewsey, J.D., W.P. Gardiner, and G. Gettinby. 2001. A study of type II and type III power for testing hypotheses from unbalanced factorial designs. Communication in Statistics - Simulation and Computation 30(3): 597-609.

Mansfield, A.W., T.G. Smith and B. Beck. 1975. The narwhal, *Monodon monoceros*, in eastern Canadian waters. Journal of the Fisheries Research Board of Canada. 32: 1041-1046.

Marcoux, M., M. Auger-Methe and M.M. Humphries. 2009. Encounter frequencies and grouping patterns of narwhal in Koluktoo Bay, Baffin Island. Polar Biology. 32:1705-1716.

Marcoux, M., M. Auger-Methe, E.G. Chmelnitsky, S.H. Ferguson and M.M. Humphries. 2011. Local passive acoustic monitoring of narwhal presence in the Canadian Arctic: A pilot project. Arctic. 64(3): 307-316.

Matthews, J.N.S., and D.G. Altman. 1996. Interaction 2: Compare effect sizes not *P* values. BMJ 313: 808.

Miller, L.A., J. Pristed, B. Mohl and A. Surlykke. 1995. The click sounds of narwhals (*Monodon monoceros*) in Inglefield Bay, Northwest Greenland. Marine Mammal Science. 11: 491-502.

National Marine Fisheries Service (NMFS). 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 pp.

Ootova, A. 2017. Marine Mammal Observer, Pond Inlet Hunting and Trapping Organization, Nunavut. Personal communication with A. Allen, documented in Ad Lib 2017 Field Notebook. 4 August 2017.

Pilleri, G. 1983. Remarks on the ecology and behaviour of the narwhal (*Monodon monoceros*), with particular reference to the savssat. Investigations on Cetacea. 15: 123-142.

Quijano, J.E., C. O'Neill and M. Austin. 2017. Underwater Noise Assessment for the Mary River Phase 2 Expansion Project: Construction and operation activities in Milne Port and along the proposed northern shipping corridor. Document 01372, Version 1.0. Technical report by JASCO Applied Sciences for Golder Associates Ltd.

R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL www.R-project.org

Rasmussen, M.H., J.C. Koblitz and K.L. Laidre. 2015. Buzzes and high-frequency clicks recorded from narwhals (*Monodon monoceros*) at their wintering ground. Aquatic Mammals. 41(3): 256-264.

Reeves, R., C. Rosa, J.C. George, G. Sheffield and M. Moore. 2012. Implications of Arctic industrial growth and strategies to mitigate future vessel and fishing gear impacts on bowhead whales. Marine Policy 36:454-62.

Remnant, R.A. and M.L. Thomas. 1992. Inuit traditional knowledge of the distribution and biology of High Arctic narwhal and beluga. Unpublished report by North/South Consultants Inc. Winnipeg, Manitoba. vii + 96 p.

Richard, P.R., J.L. Laake, R.C. Hobbs, M.P. Heide-Jørgensen, N.C. Asselin and H. Cleator. 2010. Baffin Bay narwhal population and distribution and numbers: Aerial surveys in the Canadian High Arctic, 2002-2004. Arctic. 63:85-99.

Richard, P.R., P. Weaver, L. Dueck and D. Barber. 1994. Distribution and numbers of Canadian High Arctic narwhals (*Monodon monoceros*) in August 1984. Meddelelser om Gronland Bioscience. 39: 41-50.

Richardson, W.J., D.H. Thomson, C.R. Green Jr. and C.I. Malme. 1995. Marine mammals and noise. Academic Press, Inc., San Diego, CA.

Shapiro, A. D. 2006. Preliminary evidence for signature vocalizations among free-ranging narwhals (*Monodon monoceros*). The Journal of the Acoustical Society of America. 120(3):1695-1705.

Smith, H.R., J.R. Brandon, P. Abgrall, M. Fitzgerald, R.E. Elliott and V.D. Moulton. 2015. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 30 July - 8 September 2014. Final LGL Report No. FA0013-2. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., S. Raborn, M. Fitzgerald and V.D. Moulton. 2016. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 29 July – 5 September 2015. LGL Report No. FA0044-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., V.D. Moulton, S. Raborn, P. Abgrall, R.E. Elliott and M. Fitzgerald. 2017. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 2016. LGL Report No. FA0089-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Jr., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A. and Tyack, P. L. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals. 33 (4).

Southall, B. L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten., A.E. Bowles, W.T. Ellison, D.P. Nowacek and P.L. Tyack. 2019. Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects. Aquatic Mammals. 45(2): 125-232.

Steltner, H., S. Steltner, and D.E. Sergeant. 1984. Killer whales, Orcinus orca, prey on narwhals, Monodon monoceros: an eyewitness account. Canadian Field Naturalist. 98: 458-462.

Stewart, D.B. 2001. Inuit knowledge of belugas and narwhals in the Canadian Eastern Arctic. Report for the Department of Fisheries and Oceans Canada. Arctic Biological Consultants. Winnipeg, Manitoba. 32 p.

Thomas, T.A., S. Raborn, R.E. Elliott and V.D. Moulton. 2015. Marine mammal aerial surveys in Eclipse Sound, Milne Inlet, Navy Board Inlet, and Pond Inlet, 1 August – 22 October 2014. Final LGL Report No. FA0024-2. Prepared by LGL Limited, King City, ON for Baffinland Iron Mines Corporation, Oakville, ON. 70 p.

Thomas, T.A., S. Raborn, R.E. Elliott and V.D. Moulton. 2016. Marine mammal aerial surveys in Eclipse Sound, Milne Inlet and Pond Inlet, 1 August – 17 September 2015. LGL Report No. FA0059-3. Prepared by LGL Limited, King City, ON for Baffinland Iron Mines Corporation, Oakville, ON. 76 p. + appendices.

Veirs, S., V. Veirs and J.D. Wood. 2016. Ship noise extends to frequencies used for echolocation by endangered killer whales. Peer J. 35 pp.

Watt, C.A. and S.H. Ferguson. 2015. Fatty acids and stable isotopes (δ13C and δ15N) reveal temporal changes in narwhal (*Monodon monoceros*) diet linked to migration patterns. Marine Mammal Science. 31(1): 21-44.

Watt, C.A., M.P. Heide-Jørgensen and S.H. Ferguson. 2013. How adaptable are narwhal? A comparison of foraging patterns among the world’s three narwhal populations. Ecosphere. 4(6): 71. 15 pp.

Watt, C.A., J.R. Orr, M.P. Heide-Jorgensen, N.H. Nielsen and S.H. Ferguson. 2015. Differences in dive behaviour among the world’s three narwhal *Monodon monoceros* populations correspond with dietary differences. Marine Ecology Progress Series. 525: 273-285.

Watt, C.A., J.R. Orr and S.H. Ferguson. 2017. Spatial distribution of narwhal (*Monodon Monoceros*) diving for Canadian populations helps identify important seasonal foraging areas. Canadian Journal of Zoology. 95: 41-50.

Williams, R., C. Erbe, E. Ashe, A. Beerman, and J. Smith. 2013. Severity of killer whale behavioural responses to ship noise: A dose-response study. Marine Pollution Bulletin. 79: 254-260.

Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural response of killer whaes (Orcinus orca) to whale-watching boats: opportunistic observations and experimental approaches. Journal of Zoology. 256: 255-270.

Zuur A.F., Ieno E.N., Walker N., Saveliev A.A. and Smith G.M. 2009. Mixed effects models and extensions in ecology with R. (2009). Springer.

APPENDIX A

Training Manual

REPORT

2019 Bruce Head Shore-based Monitoring Program

Training Manual

Submitted to:

Baffinland Iron Mines Corporation

2275 Upper Middle Road East - Suite 300
Oakville, ON L6H 0C3

Attention: Megan Lord-Hoyle

Submitted by:

Golder Associates Ltd.

2nd floor, 3795 Carey Road, Victoria, British Columbia, V8Z 6T8, Canada

+1 250 881 7372

1663724-138-R-Rev0

23 July 2019

Distribution List

1 copy - Baffinland Iron Mines Corporation

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Golder will undertake and manage the 2019 Bruce Head shore-based monitoring program (the Program) to investigate the behavioural response of marine mammals to vessel traffic serving Milne Port as part of Baffinland Iron Mines Corporation's Mary River Project (the Project). The Program is based at Bruce Head, a high rocky peninsula (215 m above sea level) on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route (Figure 1: , Figure 2, Figure 3) and providing a mostly-unobstructed view of Milne Inlet from the south end of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south. The primary objective of the Program is to evaluate potential disturbance of narwhal from shipping activities along the Northern Shipping Route that may result in changes in animal distribution, abundance, and migratory movements throughout Milne Inlet.

The 2019 Program represents the seventh consecutive year of environmental effects monitoring undertaken at Bruce Head in support of the Project. Previously developed by LGL Limited (LGL) in 2013 and implemented until 2016, the Program was assumed by Golder Associates beginning in 2017. Due to safety concerns associated with the distance that the team was required to travel between the Bruce Head camp and the observation platform each day, as well as concerns raised about the integrity of the previous observation platform, the Program was temporarily moved to a vessel-based platform in 2018 while plans to relocate and renovate the camp and observation platform were being drafted. Following the relocation of camp adjacent to a newly constructed observation platform in 2019, data collection from the shore-based observation platform will resume this season. The new observation platform consists of a modified seacan securely anchored to the ground, providing the field team with protection from the elements.

The 2019 study design is similar to that applied in previous survey years (2014-2017), with data collected on narwhal relative abundance and distribution (RAD) within a defined Stratified Study Area (SSA); on group composition and behaviour within a 1-km Behavioural Study Area (BSA); and on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors which may also affect narwhal behaviour.

As will be discussed in greater detail in Section 2.0, changes to the 2019 study design include an extension of the SSA boundary to include the mouth of Koluktoo Bay, and integration of acoustic data collection and UAV data collection.

Figure 1: Camp at Bruce Head, overlooking Poirier Island and Milne Inlet.

Figure 2: Camp at Bruce Head, overlooking Milne Inlet.

Figure 3: Camp at Bruce Head, with southern Milne Inlet in the background.

1.1 Study Area

The Study Area is approximately 6 km wide on average and is comprised of the broader Stratified Study Area (SSA) and, nested within the SSA, the Behavioural Study Area (BSA) (Figure 4). The SSA is stratified into strata A (northernmost stratum) through K (southernmost stratum) and further separated into substrata 1 through 3 (1 being closest to the Bruce Head shore and 3 being the furthest away). There are a total of 30 substrata within the SSA as strata D, J and K are comprised of only 2 substrata each. The boundaries of each substratum are visually estimated in the field using land marks. The BSA covers portions of strata D, E, and F that are within 1 km of the Bruce Head shore where the observation platform is located.

Beginning in 2019, the SSA will be expanded westward to include strata J and K. The objective of including additional strata is to systematically capture the "pulsing" of narwhal in and out of Koluktoo Bay that has been observed anecdotally in past monitoring programs (Golder 2018, Smith et al. 2015, Smith et al. 2016, Smith et al. 2017). It should be noted that the precise boundary of strata J and K may be modified based on the field of view determined by the MMOs once at site. It is expected that the majority of Koluktoo Bay beyond the western boundary of strata K will not be visible to MMOs from the vantage point of the observation platform at Bruce Head.

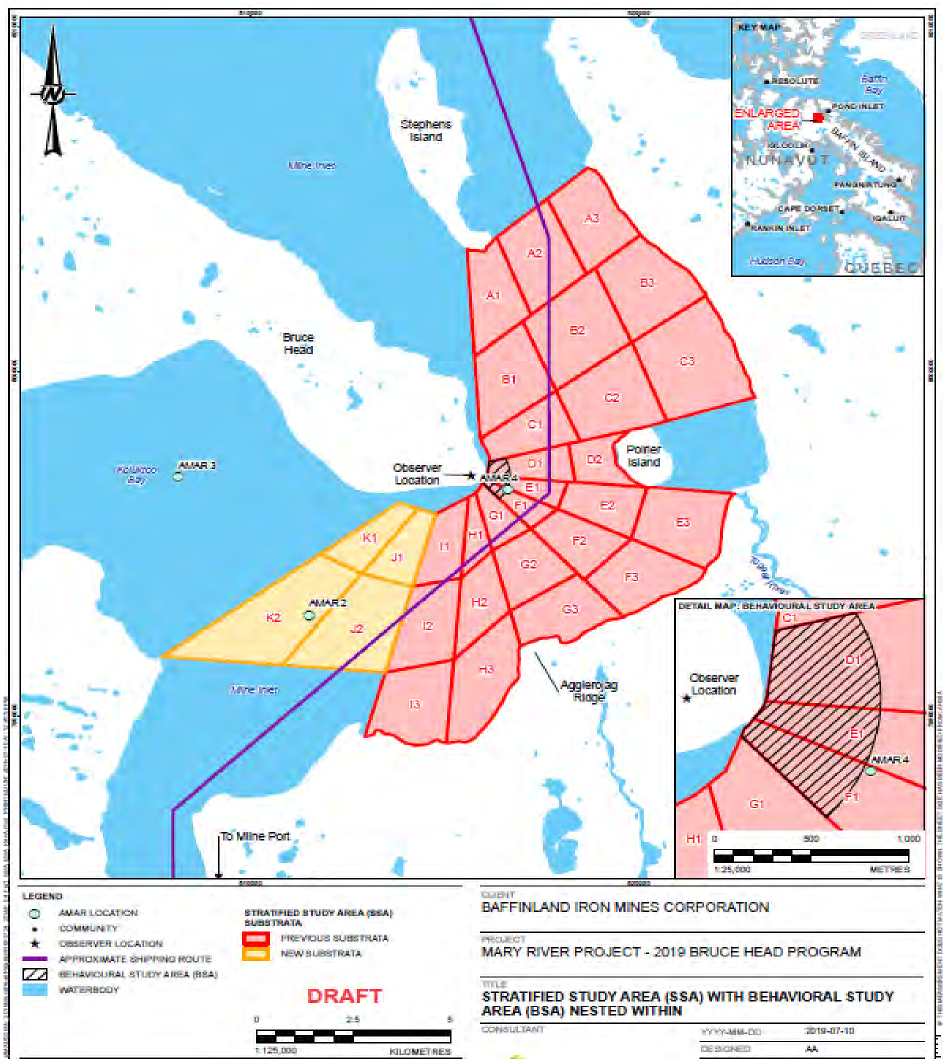


Figure 4: Stratified Study Area (SSA) with Behavioural Study Area (BSA) nested within.

2.0 CHANGES TO 2019 STUDY DESIGN

Based on collection and analysis of data obtained during previous Bruce Head Shore-based monitoring Programs, as well as consultation with the various stakeholder groups, it was determined that certain modifications to the study design would provide for a more comprehensive picture of potential effects to narwhal resulting from Project-related shipping activities. Of note, changes to the 2019 study design include an extension of the SSA boundary to include the mouth of Koluktoo Bay, and integration of acoustic data collection and UAV data collection.

2.1 Amendment of Stratified Study Area Boundary

The existing Stratified Study Area (SSA) has been expanded for the 2019 field season to include additional strata (J and K) with the aim of evaluating narwhal movements at the mouth of Koluktoo Bay in relation to vessel traffic (Figure 4). Of particular interest is the apparent 'pulsing' of narwhal groups in and out of Koluktoo Bay that has been observed anecdotally in past years (Golder 2018, Smith et al. 2015, Smith et al. 2016, Smith et al. 2017), and whether these movements are related to vessel disturbance or simply to variation in their natural habitat (e.g. tidal cycles, prey availability, etc).

The spatial extent of Koluktoo Bay beyond the revised SSA boundary that will be visible to MMOs stationed at the observation platform is yet to be confirmed (Figure 4). Therefore, it is expected that the western boundary of substrata K will be updated to reflect the actual field of view upon the field team's arrival to site.

2.2 Integration of Acoustic Data Collection

Comparison of direct visual observations of marine mammals with concurrently collected acoustic and Automatic Identification System (AIS) datasets is an effective way to assess the potential effects of shipping on animal behaviour. Three Autonomous Multichannel Acoustic Recorders (AMARs) deployed in the vicinity of Bruce Head and Koluktoo Bay (Figure 4) will record acoustic data during the 2019 open-water season. The objectives of collecting acoustic data at Bruce Head concurrently with visual observations are as follows:

- Characterize ambient sound levels and fluctuations in the acoustic environment as a result of project-related vessel traffic;
- Characterize narwhal call rates and repertoire in relation to vessel presence, direction of travel, and orientation (University of New Brunswick collaboration; Crystal Prieur);
- Characterize narwhal behaviour (strictly visual, not acoustic) in relation to fluctuating sound fields as a result of project-related vessel traffic (University of New Brunswick collaboration, Sam Sweeney);
- Identify marine mammal presence not captured by visual observations;
- Evaluate project-related vessel sound levels in relation to established marine mammal acoustic thresholds for disturbance and injury; and
- Determine call rates of narwhal and subsequently estimate animal densities via passive acoustic monitoring alone (this is a future objective as it will be informed by baseline data collected as outlined in the previous bullet points).

Visual observations of narwhal at Bruce Head will be correlated with concurrently collected acoustic data via a survey new to this Program, termed the Visual Acoustic Correlation (VAC) Survey (Section 4.2.3).

2.3 Integration of UAV Survey

Golder is proposing to conduct a survey of narwhal in the vicinity of Bruce Head using an UAV (Unmanned Aerial Vehicle). The integration of this component of the study is contingent on obtaining a BVLOS (Beyond Visual Line of Sight) permit from Transport Canada.

Should Golder be successful in obtaining a BVLOS permit, an UAV will be flown along a specified flight path to collect data on narwhal relative abundance and distribution throughout the SSA and in Koluktoo Bay. Data collected from the UAV will be used to ground troth sightability of narwhal from the vantage point of the observation platform and to provide “snapshots” of number of animals in the vicinity of the AMARs in order to inform narwhal acoustic behaviour and call rates.

3.0 SCHEDULE

The 2019 Bruce Head Shore-based Monitoring Program will consist of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of 5 individuals each (‘Early shift’ and ‘Late shift’), alternating at 4 hr observation intervals (Table 1). Individuals will work with their respective teams throughout the duration of their time at Bruce Head and will alternate working the ‘Early’ or ‘Late’ shift according to a 3-day rotation schedule (Table 2). The team that is not monitoring narwhal during their 4-hr shift will have the opportunity to rest and prepare/eat meals during this time.

Table 1: Daily monitoring schedule and time available for meals.

Time (EDT)	Monitoring Narwhal	Meals
Before 06:00	N/A	Breakfast (Early shift)
06:00 – 10:00 (4 hrs)	Early shift	Breakfast (Late shift)
10:00 – 14:00 (4 hrs)	Late shift	Lunch (Early shift)
14:00 – 18:00 (4 hrs)	Early shift	Lunch / Dinner (Late shift)
18:00 – 22:00 (4 hrs)	Late shift	Dinner (Early shift)

Table 2: 2019 Monitoring Schedule[1]

Date (2019)	Early Shift	Late Shift
July 31, August 1	N/A: Training / set-up camp (everyone)	
August 2, 3, 4	AA, SS, MF, AO*, MA, JT	SU, BC, JM*, PA, LK
August 5, 6, 7	SU, BC, JM*, PA, LK	AA, SS, MF, AO*, MA, JT
August 8, 9, 10	AA, SS, MF, AO*, MA, JT	SU, BC, JM*, PA, LK
August 11, 12, 13	SU, BC, JM*, PA, LK	AA, SS, MF, AO*, MA, JT
August 14, 15	N/A: Crew change / training (leg 2)	
August 16, 17, 18	KZ, BW, JJT*, BT, RA	AJ, SS, TT, JT*, VK, MI
August 19, 20, 21	AJ, SS, TT, JT*, VK, MI	KZ, BW, JJT*, BT, RA
August 22, 23, 24	KZ, BW, JJT*, BT, RA	AJ, SS, TT, JT*, VK, MI
August 25, 26, 27	AJ, SS, TT, JT*, VK, MI	KZ, BW, JJT*, BT, RA
August 28, 29, 30	KZ, BW, JJT*, BT, RA	AJ, SS, TT, JT*, VK, MI
August 31, September 1, 2	AJ, SS, TT, JT*, VK, MI	KZ, BW, JJT*, BT, RA
September 3, 4	N/A: Camp de-mobilization / travel	

[1] Leg 1: Ainsley Allen (AA), Adrian Ootova* (AO), Bertrand Charry (BC), Jayco Tatatuapik (JT), Justin Muckpa* (JM). Larry Kadloo (LK), Max Aniviapik (MA), Peter Jr. Amarualik (PA), Sam Sweeney (SS), Sima Usvyatsov (SU) (* denotes Polar Bear Monitor)

Leg 2: Alec Johnston (AJ), Ben Widdowson (BW), Billy jr. Tagak (BT), Johnny jr. Tawgawkak* (JJT), Juanasasi Tigullaraq* (JT), Katelyn Zottenberg (KZ), Michael Inuarak (MI), Ryan Arnakallak (RA), Sam Sweeney (SS), Trish Tomliens (TT), Victor Kadloo (VK)

4.0 PROGRAM OVERVIEW

During each 4-hr monitoring shift, three complementary surveys will be undertaken; the first survey conducted by a team of two individuals (i.e. Team 1) and the second and third surveys conducted by a team of three individuals (i.e. Team 2):

1) Relative Abundance and Distribution (RAD) surveys will be conducted throughout the SSA.
2) Group Composition and Behaviour surveys will be conducted within the BSA.
3) Anthropogenic activity and environmental conditions will be documented throughout the SSA.

There will be some redundancy in data collected, albeit to varying degrees. Specifically, both teams will collect data on glare and sightability (Team 1 for each substratum throughout the SSA during RAD surveys; Team 2 for the BSA during each 50-minute survey) and both teams will collect data on anthropogenic activity (Team 1 will note whether a vessel is entering/exiting Milne Inlet and approaching/departing individual substrata; Team 2 will note any hunting activity within and beyond the SSA and document vessels within the BSA). The reason for this is to ensure that the timing of these observations aligns with the data being collected.

The two teams will assist one another opportunistically. For example, when Team 1 is not conducting RAD counts, they may assist Team 2 in collecting photographs of narwhal within the BSA and of vessels/activities considered noteworthy within the SSA. Conversely, when narwhal are not present in the BSA, Team 2 may assist in collecting anecdotal information within the broader SSA.

4.1 Team 1 - Relative Abundance and Distribution (RAD)

A team of two individuals (Team 1) will collect relative abundance and distribution data on narwhal, other cetaceans, and anecdotally on pinnipeds within the entire Stratified Study Area (SSA).

S*urvey* and *scan* sampling protocols will be used (Mann, 1999[2]) whereby the observer surveys each stratum for a minimum of 3 minutes to identify narwhal groups[3] (including a solitary narwhal which would be considered a group of 1) and count all individuals within each group. Once all narwhal present within each substratum have been counted and their direction of travel recorded, the observer moves on to the next substratum.

Data to be recorded for each substratum within the SSA:

- Number of narwhal groups and size of individual groups.
- Narwhal direction of travel (i.e., N,S,E,W, or N/A if group travel is multi-directional such as milling).
- Presence of other marine mammals.
- Vessel presence and direction of travel.
- Beaufort scale, glare and a subjective assessment of sightability (see section 4.1.3).

[2] Mann, J. 1999. Behavioural sampling methods for cetaceans: a review and critique. Marine Mammal Science 15(1): 102-122.

[3] Group = individuals within one body length of one another.

4.1.1 Roles and Responsibilities – Team 1

Table 3: Team 1 roles, responsibilities, and monitoring equipment employed.

Team Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	■ Count all visible narwhal within each substratum and note group size and direction of travel whenever possible. ■ Note other marine mammal species observed in each substratum. All other cetaceans (whales) observed are to be documented as a separate sighting while any pinnipeds (seals) and walrus observed are to be documented anecdotally in the comments section. ■ Report beaufort scale, glare and sightability within each substratum. ■ Document vessel presence in relation to each substratum and hunting/shooting activity whenever possible. This will be documented in greater detail by Team 2. ■ Communicate all observations to the Recorder.	10x42 binoculars
Person 2 – Recorder	■ Record all information received from the MMO using the RAD data sheet. All times should be recorded using the 24-hr clock (e.g. 2 pm is recorded as 14:00).	Data sheet[4]

4.1.2 Survey Protocol - RAD

- Observations of the SSA will be made by a team of two individuals (Team 1) from two pre-determined observation locations (15 m apart) that provide an overview of strata A to F, and G to K, respectively.
- RAD counts are to be undertaken at the start of each observation period and every hour, on the hour, during the 10-hr observation period.
- RAD counts are to be undertaken continuously upon visual detection of large vessels prior to entering the SSA (exact distance to be defined in the field) and for the full duration that the vessel is present within the SSA. A final RAD count is to be made once the large vessel has left the SSA. If a large vessel enters the SSA mid-way through conducting an hourly RAD count, that count is to be completed and another count will commence immediately after.
- General Rules:
  - If majority of narwhal are travelling in one direction (i.e. north → south), begin counting the strata from the opposite direction (i.e. south → north) in order to avoid / minimize double counting.
  - During incoming vessels, begin counts in the stratum closest to the incoming vessel.
  - Other whales observed in each substratum are to be documented as an individual sighting while seals and walrus observed are to be documented in the comments section of the data sheet.
  - The observer is to spend a minimum of 3 minutes scanning each stratum (i.e. 1 minute per substratum).
  - Data will not be collected for a substratum that cannot be observed in its entirety due to weather. When a substratum is omitted due to weather, glare and sightability must still be documented.

[4] Data Sheets: Relative Abundance and Distribution

4.1.3 Additional data to be collected

In addition to the RAD data collected by Team 1, the team will document the following during each RAD survey:

- Record all whale sightings as you would a narwhal sighting (as a separate line item in datasheet).
- For seal and walrus sightings within each substratum, include a descriptive comment in the data sheet including information on species, group size, and behaviour (as possible). Always prioritize whale sightings.
- Vessel presence, vessel class[5], and direction of travel (i.e., entering or exiting Milne Inlet and approaching or departing substratum) within individual substratum.
- Specific environmental conditions for individual substratum:
  - Beaufort scale (see Appendix B)
  - Glare: severe (S), light (L), none (N).
  - Sightability (a subjective assessment of the overall viewing conditions):
    - Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
    - Good (G): conditions such that marine mammals at surface would *very likely* be detected.
    - Moderate (M): conditions such that marine mammals at surface may be detected.
    - Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
    - Impossible (I): water is completely obscured by fog, ice, or high sea state.

4.2 Team 2 - Group Composition and Behaviour

A team of three individuals (Team 2) will collect group composition and nearshore behavioural data on all narwhal that swim within 1 km from the shore where the observation platform is located (i.e. the BSA). Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods. S*urvey* and *scan* sampling protocols will be used (Mann, 1999). For each sighting[6], the team will collect data as per the survey protocol outlined below, after which the observer will move on to the next sighting.

Data to be recorded for the BSA:

- Narwhal group composition.
- Narwhal group primary and secondary behaviour.
- Beaufort scale, glare, and an assessment of sightability (as per definitions in Section 4.1.3).

[5] Vessel class: Small = 0-50m; medium = 50m-100m; large = $\geq$100m

[6] Sighting: Observation of a group of animals (including groups of 1).

Team 2 will also collect data on the following for the entire SSA:

- Vessel presence, class (e.g., large, medium, and small), and direction of travel.
- Any hunting/shooting events, the associated time, and target species whenever possible.
- Environmental data (i.e. ice cover, precipitation, cloud cover).

Additionally, Team 2 will be responsible for documenting narwhal distance and orientation in relation to the Autonomous Multichannel Acoustic Recorder (AMAR) so that visual and acoustic observations of narwhal can be correlated.

4.2.1 Roles and Responsibilities – Team 2

Table 4: Team 2 roles, responsibilities, and monitoring equipment employed.

Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	■ Document group composition as well as primary and secondary behaviour of all narwhal within the BSA. Specific behaviour (e.g. tusking) within each of the seven behavioural categories should be documented whenever possible. ■ Note any other marine mammal species (and behaviour) observed in the BSA ■ Report glare and sightability within the BSA every hour. ■ Communicate all observations to the Recorder (Person 2).	Big eye binoculars
Person 2 – Recorder (Visual Observations of Narwhal)	■ Record all information received on the data sheet from the MMO. ■ Observe environmental conditions and complete the associated data sheet every hour and whenever conditions change. ■ Document which sightings are included by Person 3 in the hourly VAC Survey. For sightings documented by Person 3, Include a check mark (√) in the final column of the Group Composition and Behaviour Survey datasheet. ■ Complement the data collected by taking photographs of narwhal within the BSA and of vessels in the SSA whenever time permits. ■ All times should be recorded using the 24-hr clock LOCAL TIME (e.g. 2 pm is recorded as 14:00)	HD camera, 10 x 42 binoculars, Datasheets[7]
Person 3 – Recorder / Observer (Anthropogenic and Acoustic Observations)	■ Complete the Visual Acoustic Correlation (VAC) survey every hour, on the hour. This should be a "snapshot" of narwhal location and orientation in relation to AMAR 4 so should be documented with a single timestamp. If more time is required to accurately document all narwhal, a timestamp range should be included on the datasheet (e.g. 12:34 – 12:37). ■ For narwhal within the BSA, communicate to Person 2 which sightings are included in the hourly VAC Survey. ■ For vessels present within the SSA, document vessel class and specify whether entering/exiting Milne Inlet and approaching/departing the BSA. ■ Record all hunting activity throughout each 4-hr observation period, the associated time, and the target species whenever possible. ■ Once datasheets have been completed, assist Person 1 with marine mammal observing.	10 x 42 binoculars, Datasheets[8],

[7] Datasheets: Group Composition and Behaviour; Environmental Conditions
[8] Datasheets: Vessel Passages and other Anthropogenic Activity; Visual-Acoustic Correlation (VAC) Survey

4.2.2 Survey Protocol – Group Composition and Behaviour

- Observations of narwhal group composition and behaviour will be made by the **Team 2 MMO** who will communicate findings to the **Team 2 Recorder.**
- The **Team 2 Recorder** will also be responsible for documenting environmental conditions for the entire SSA every hour and whenever conditions change,
- The third individual from Team 2, the **Recorder of Anthropogenic and Acoustic Observations**, will be responsible for collecting vessel traffic and anthropogenic data for both the BSA and the broader SSA and will assist the MMO with observations once completing the VAC Survey (Section 4.2.3).
- The three individuals that are part of Team 2 will be stationed at the observation platform.
- Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods.
- General Rules:
  - Primary[9] (1) and secondary[10] (2) behavioural data are to be recorded for every sighting whenever possible, based on seven behavioural categories[11] (Table 8).
  - Unique behaviours[12] are also to be recorded in the datasheet whenever observed.
  - If majority of narwhal are travelling through the BSA in one direction (i.e. north → south), begin counting and characterizing the animals from the opposite direction (i.e. south → north).
  - Herding events[13]: If multiple groups pass through the BSA too quickly such that group composition and behaviour cannot be recorded (based on best judgment of **Team 2 MMO**), counts should be conducted, and the sightings grouped into 5-minute bins. One herding event may have multiple 5-minute sightings that will be added together at a later time to determine the total group size of the herding event. In this scenario, the **Team 2 Recorder** is to announce the completion of each 5-minute interval, the count is to be recorded, and the **Team 2 MMO** then begins counting (and characterizing whenever possible) the next sighting, beginning the count again at 1.
  - If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be 'resighted' every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.

The following tables outline the group composition data (Table 5 and associated tables) and the behavioural data (Table 8) that is to be recorded for each sighting[14] within each 50-minute survey.

---

[9] Primary behaviour = the behaviour displayed by the majority of animals; the predominant behaviour.

[10] Secondary behaviour = the second most commonly observed behaviour of a group of animals.

[11] Behavioral categories (see Table 8) = travelling, resting, milling, foraging, socializing, reproductive, other.

[12] Unique behaviours (see Table 8) = logging (LO), chase prey (CH), catch prey (CA), rubbing/petting (RU), rolling (RO), tusk (TU), tail slap (TS), nursing (NU), mounting (MO), sexual display (SX), bubble rings (BU), spyhopping (SP), breaching (BR), diving (DY).

[13] Herding event = numerous groups of animals swimming in the same direction.

[14] Sighting = observation of a group of animals (including groups of 1).

Table 5: Group composition and behaviour data to be recorded.

Data to be recorded	Description
Time of sighting	For every sighting, time of passage through the BSA must be recorded. See ‘General rule’ for herding events above.
Sighting #	For each group of animals observed in the BSA, a sighting number is to be used as a unique identifier. If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be ‘resighted’ every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.
Whale species	Although narwhal are the focal species of this program, all other whale species observed are to be recorded as a separate sighting (with the same level of detail as would be provided for narwhal). Seals and walrus are to be noted in the comments section only.
Group size	Number of narwhal within 1 body length of one another. Includes group size of 1.
Number of narwhal with tusks	■ Present ■ Absent ■ Unknown (i.e. head not visible).
Number of narwhal in age categories adult, juvenile, yearling, and calf.	See Table 6 (Life stages).
Spread	■ Tight: narwhal ≤ body width apart ■ Loose: narwhal >1 body width apart
Group Formation	See Table 7 (Formation).
Direction of travel	N, S, E, W
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer:>300m
Primary & Secondary Behaviour	■ See Table 8 (Behavioural Data).
Associated photo range	■ For each sighting where photos are taken, the numeric photo range should be recorded.

Table 6: Life stages of narwhal.

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% length of adult	2/3 of accompanying female	½ length of accompanying female, usually in “baby” or “echelon” position close to mother. Newborn calves are ~1.6 m in length.
Colouration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey

Table 7: Group formation categories.

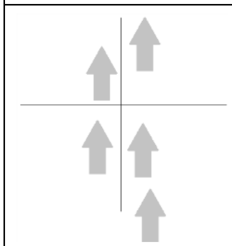
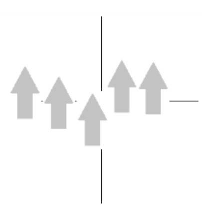
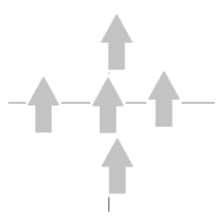
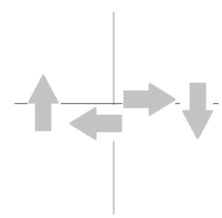
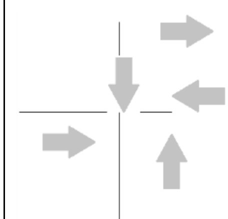
Linear	Parallel	Cluster/ circular	Non-directional line	No formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight line	Animals swimming next to each other in a line formation	Animals swimming in cross formation (equally long as wide lines)	Animals in a linear line but facing different directions	Equal spread with no clear pattern
				

Table 8: Behavioural data (primary and secondary) to be recorded.

Behaviour	Description of behaviour	Unique behaviour examples
Travelling	Animal(s) exhibiting directed movement; moving steadily in a constant direction	-
Resting	Animal(s) not moving	Logging (LO)
Milling	Animal(s) exhibiting non-directional movement; moving about haphazardly within a limited area	-
Foraging	Animal(s) chasing or catching prey species	Chase prey (CH) Catch prey (CA)
Socializing	Animal(s) in physical contact with one another; includes tail slaps	Rubbing or petting (RU) Rolling (RO) Tusk displays or tusk contact (TU) Tail slap (TS)
Reproductive	Animal(s) exhibiting behavior known to be related to reproductive function	Nursing (NU) Mounting (MO) Sexual display (SX)
Other	Animal(s) exhibiting behavior not known to be context-related. A description of behavior is to be included in comments.	Bubble rings (BU) Spyhopping (SP) Breaching (BR) Diving (DY)

4.2.3 Survey Protocol – Visual Acoustic Correlation (VAC)

- Every hour, on the hour, the third individual from Team 2, the **Recorder of Anthropogenic and Acoustic Observations**, will be responsible for documenting narwhal distance and orientation in relation to AMAR 4 by filling out the Visual Acoustic Correlation (VAC) Survey datasheet.
- General Rules:
  - The location and orientation of narwhal groups within 900 m from AMAR 4 will be recorded on the datasheet in 300 m increments using the following notation:
    - Circle encasing the number of animals in the group <u>with arrow</u> for groups showing clear direction/ orientation relative to the AMAR.
    - Circle encasing the number of animals in the group <u>with no arrow</u> for groups showing none or mixed orientation relative to the AMAR.
  - To the best extent possible, provide a "snapshot" of narwhal groups in the vicinity of AMAR 4 by recording all observations within one minute. Where more time is required due to challenging sighting conditions or herding events, document the time needed to collect the "snapshot" (e.g. 12:41 – 12:44).
  - Communicate to the **Team 2 Recorder** (Person 2) which narwhal groups observed are included in the hourly VAC Survey and ensure that this is recorded by the **Team 2 Recorder** (Person 2) in the final column of the Group Composition and Behaviour datasheet.
  - Survey # recorded on the VAC Survey datasheet should correspond with the survey # on the Group Composition and Behaviour Survey datasheet.
  - The VAC Survey datasheet is to be filled out even when no narwhal are visible.
  - For documenting narwhal presence, circle "Y" (Yes) if narwhal are clearly present within/beyond the 900 m radius, "N" (No) if no narwhal are clearly present within the 900 m radius, and "U" (Unknown) if no narwhal are clearly present beyond the 900 m radius. As the VAC is intended to be a "snapshot" in time, it is not possible to comprehensively survey the entire SSA within a one-minute period and confirm narwhal absence. Therefore, narwhal absence beyond the 900 m radius will be later assessed by reviewing RAD data collected concurrently.

4.2.4 Additional data to be collected

In addition to Team 2 collecting group composition and behavioral data within the BSA, the following environmental conditions are to be observed <u>for the entire SSA</u> and documented by the **Team 2 Recorder** upon arrival to the observation site each day, every hour, and whenever conditions change:

- Ice cover (%) in entire SSA
- Precipitation type: rain, fog, snow, or none
- Cloud cover (%)

The following environmental conditions are to be observed by the **Team 2 MMO** and recorded by the **Team 2 Recorder** for the BSA upon arrival to the observation site each day, every hour, and whenever conditions change:

- Beaufort Scale (see Appendix B)
- Glare: severe (S), light (L), none (N)
- Sightability (a subjective assessment of the overall viewing conditions):
  - Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
  - Good (G): conditions such that marine mammals at surface would *very likely* be detected.
  - Moderate (M): conditions such that marine mammals at surface may be detected.
  - Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
  - Impossible (I): water is completely obscured by fog, ice, or high sea state.

All vessels present and hunting activity observed within the SSA (including the BSA) will be documented by the **Team 2 Recorder of Anthropogenic and Acoustic Observations**. The following will be recorded:

- Vessel class[15] for all vessel traffic present within the SSA.
- The time, duration, and general location of all hunting activity observed (visually or aurally) during each 50-minute survey, noting the target species whenever possible.
- Fixed-wing aircraft and helicopters are to be noted in the ‘comments’ section of the data sheet if present, including aircraft travel direction.

[15] Vessel class: Small = 0-50m; medium = 50m-100m; large = $\geq$100m

5.0 LITERATURE CITED

Golder Associates Ltd. (Golder). 2018. 2017 Bruce Head Shore-based Monitoring Program. Final report submitted to Baffinland Iron Mines Corporation. Report No. 1663724-041-R-Rev1. 19 April 2018.

Mann, J. 1999. Behavioural sampling methods for cetaceans: a review and critique. Marine Mammal Science 15(1): 102-122.

Smith, H.R., J.R. Brandon, P. Abgrall, M. Fitzgerald, R.E. Elliott, and V.D. Moulton. 2015. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 30 July - 8 September 2014. Final LGL Report No. FA0013-2. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., V.D. Moulton, S. Raborn, P. Abgrall, R.E. Elliott, and M. Fitzgerald. 2017. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 2016. LGL Report No. FA0089-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Smith, H.R., S. Raborn, M. Fitzgerald, and V.D. Moulton. 2016. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 29 July – 5 September 2015. LGL Report No. FA0044-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Signature Page

Golder Associates Ltd.

Ainsley Allen, MSc
Marine Biologist

Phil Rouget, MSc, RPBio
Senior Marine Biologist

AA/PR/lih

o:\final\2016\3 proj\1663724 baff_marinemammalsurvey_ont\1663724-138-r-rev0\1663724-138-r-rev0-bruce head2019 training manual 23jul_19.docx

APPENDIX A

Glossary

Group size – all narwhal within one adult body length of each other.

Beaufort Scale – a scale of wind speed based on a visual estimation of the wind's effect, from Beaufort force 1 (calm) to Beaufort force 12 (hurricane). See Appendix B for the Beaufort Scale.

Behaviour

Table 1: Behavioral Data (primary and secondary) to be Recorded

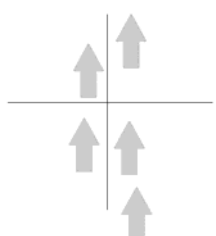
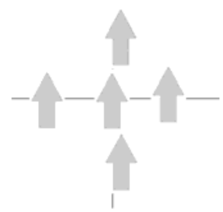
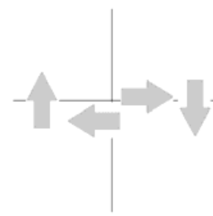
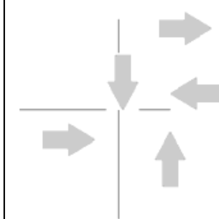
Behavior	Unique Behaviours to be Recorded	Description of Behavior
Travelling		Directed movement; moving steadily in a constant direction
Resting	Logging (LO)	Not moving
Milling		Non-directional movement; moving about haphazardly within a limited area
Foraging	Chase prey (CH) Catch prey (CA)	
Socializing	Rubbing or petting (RU) Rolling (RO) Tusk displays or tusk contact (TU) Tail slap (TS)	Animals in physical contact with one another
Reproductive	Nursing (NU) Mounting (MO) Sexual display (SX)	
Other	Bubble rings (BU) Spyhopping (SP) Breaching (BR)	Behaviours not known to be context-related. Description of behaviour observed to be included in comments.

BSA – Behavioural Study Area covers portions of strata D, E and F that are within 1 km of the Bruce Head shore where the observation platform is located.

Glare – reflections of the sun on the water, categorized as either None, Light, or Severe.

Group Formation – The configuration of the shape that narwhal within a group swim together, these are categorized as in the table below.

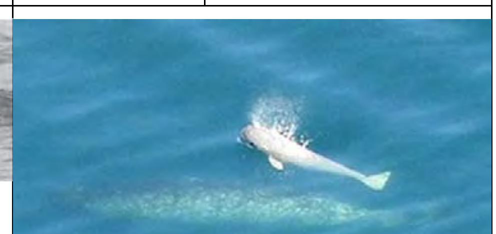
Table 2: Group Formation Categories

Linear	Parallel	Cluster/Circular	Non-Directional Line	No Formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight line	Animals swimming next to each other in a line formation	Animals swimming in cross formation (equally long as wide lines)	Animals in a linear line but facing different directions	Equal spread with no clear pattern
				

Herding – numerous groups of narwhal swimming in the same direction.

Narwhal Life Stages

Table 3: Life Stages of Narwhal

	Adult	Juvenile	Yearling	Calf
	4.2 – 4.7 m	80-85% length of adult	2/3 of accompanying female	½ length of accompanying female, usually in "baby" or "echelon" position close to mother. Newborn calves are ~1.6 m in length.
Colouration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey
Photo	 			

RAD counts – Relative Abundance and Distribution counts of narwhal and any other marine mammals encountered within the SSA.

Primary behaviour – the behavior displayed by the majority of animals; the predominant behavior.

Secondary behaviour – the second most commonly observed behavior of a group of animals.

Sightability – categorized as Excellent, Good, Moderate, Poor, or Impossible. Sightability is a ranking descriptor for the overall ‘detectability’ of a marine mammal given the combined influence of sea state, visibility and glare conditions. For example, the combined effect of a low sea state, excellent visibility, and no sun glare would result in ‘Excellent’ sightability conditions, while the combined effect of high sea state, poor visibility, and high glare would result in ‘Poor’ or even “Impossible” sightability conditions.

- Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
- Good (G): conditions such that marine mammals at surface would *very likely* be detected.
- Moderate (M): conditions such that marine mammals at surface may be detected.
- Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
- Impossible (I): water is completely obscured by fog, ice, or high sea state.

Spread – The extent, width, or area covered by narwhal in a group.

Tight spread – narwhal ≤ body width apart

Loose spread – narwhal >1 body width apart

Sighting – an observation of an individual or a group of animals, (including groups of 1).

SSA – Stratified Study Area, the larger study area of the program.

Stratum – Sections A to F of SSA

Substratum – Sections 1 to 3 within each stratum of the SSA.

APPENDIX B

Beaufort Scale

The Beaufort scale

No.	Knots	Mph	Description	Effects at sea	Effects on land
0	0	0	Calm	Sea like a mirror	Smoke rises vertically
1	1-3	1-3	Light air	Ripples but no foam crests	Smoke drifts in wind
2	4-6	4-7	Light breeze	Small wavelets	Leaves rustle; wind felt on face
3	7-10	8-12	Gentle breeze	Large wavelets; Crests not breaking	Small twigs in constant motion; Light flags extended
4	11-16	13-18	Moderate wind	Numerous whitecaps Waves 1-4ft high	Dust, leaves and loose paper raised. Small branches move.
5	17-21	19-24	Fresh wind	Many whitecaps, some spray; Waves 4-8 ft high	Small trees sway
6	22-27	25-31	Strong wind	Whitecaps everywhere; Larger waves 8-13 ft high	Large branches move; Difficult to use umbrellas
7	28-33	32-38	V. strong wind	White foam from waves is blown in streaks; waves 13-20ft high	Whole trees in motion
8	34-40	39-46	Gale	Edges of wave crests break into spindrift	Twigs break off trees; Difficult to walk
9	41-47	47-54	Severe gale	High waves; sea begins to roll Spray reduce visibility; 20ft waves	Chimney pots and slates removed
10	48-55	55-63	Storm	V. high waves 20-30 ft; blowing foam gives sea white appearance	Trees uprooted Structural damage
11	56-63	64-72	Severe storm	Exceptionally high waves; 30-45 ft high	Widespread damage
12	63	73	Hurricane	Air filled with foam; visibility reduced White sea; waves over 45ft high	Widespread damage; rare

APPENDIX C

Marine Mammal Detection Cues

1.0 MARINE MAMMAL DETECTION CUES

Detection cues are useful to know as they can mark the presence of marine mammals even when they have not surfaced. Below is a list of detection cues that will be useful to know when looking for marine mammals.

Blows

Marine mammals exhale when they surface, often expelling a watery mist from their blow holes or mouths (pinnipeds). These can be seen from very far distances (>15 km for blue whale blows in ideal conditions), and they may also be heard. It is possible to utilize the size and shape of the whale blow to give clues as to what type of whale it might be. Toothed whales have one blowhole and therefore discharge a blow with one short wide plume, whereas baleen whales have two blowholes that sometimes make a V-shaped or heart-shaped blow plume (see Figure 1).

Figure 1: Toothed whale blow of a killer whale (left) versus baleen whale blow of humpback and bowhead whales (right)

Splashes in the water

Splashes may be a sign that a marine mammal is present and may occur due to porpoising at high speed, tail-slapping, chasing fish, etc.

Footprints

Footprints are when the surface of the water looks disturbed and are made when a marine mammal has just been on or near the surface of the water, or produced by water movement by near-surface tail flukes.

Birds

Birds feed on schooling fish just as many marine mammals. They may be present before the arrival of a marine mammal, or at the same time. Birds may be observed in the air, on the surface of the water or diving into the water.

APPENDIX D

Marine Mammal Identification

1.0 MARINE MAMMALS IN BAFFIN ISLAND WATERS

Please see the following pages for species identification descriptions.

1.1.1 Whales

- Narwhal (*Monodon monoceros*)
- Beluga (*Delphinapterus leucas*)
- Bowhead whale (*Balaena mysticetus*)
- Killer whale (*Orcinus orca*)

Other possible but rare whales

- Minke whale (*Balaenoptera acutorostrata*)
- Northern Bottlenose whale (*Hyperoodon ampyllatu*s)
- White-beaked dolphin (*Lagenorhynchus albirostris*)

1.1.2 Seals and Polar Bear

- Harp seal (*Pagophilus groenlandicus*)
- Ringed seal (*Pusa hispida*)
- Bearded seal (*Erignathus barbatus*)
- Walrus (*Odobenus rosmarus*)
- Polar bear (*Ursus maritimus*)
- Hooded seal (*Crystophora cristata*) – rare

Beluga

Delphinapterus leucas
(Pallas, 1776)

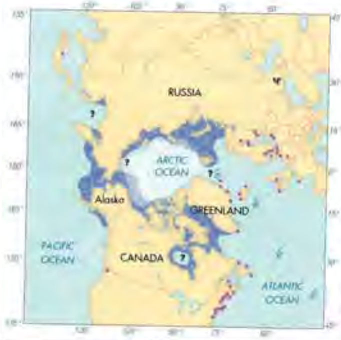
- WHITE ADULT COLORATION
- ROUNDED, MALLEABLE MELON AND FLEXIBLE NECK
- SHORT BROAD BEAK WITH CLEFT UPPER LIP
- BROAD FLIPPERS AND ORNATELY SHAPED FLUKES
- LACK OF DORSAL FIN
- OCCURS ONLY IN HIGH LATITUDES OF NORTHERN HEMISPHERE

Known by some early whalers as "sea canaries" because of their loquacious natures, these whales are abundant and widespread in the Arctic and Subarctic. For many centuries, Belugas, also known as White Whales, have been a staple of arctic societies, providing food, fuel oil, and even soft durable leather. They were among the first cetaceans to be brought into captivity. Their resilience and adaptability, stunning appearance, engaging disposition, and trainability have made them popular performers in oceanariums. Several areas where Belugas congregate have become whale-watching meccas, most notably eastern Canada's lower St. Lawrence River and the Churchill River estuary in western Hudson Bay. Over the past 15 years, there has been a flurry of research on the species, much of it involving satellite telemetry. These studies have shown that the Beluga has impressive diving abilities and is even more ice-adapted and abundant than was previously believed.

DESCRIPTION The Beluga has a rounded midsection that tapers toward the head and tail. Its torso is markedly rotund when the animal is well fed. The head is unlike that of any other cetacean, with a bulging melon that one researcher described as feeling like a balloon filled with warm lard. A Beluga is able to change the shape of its melon at will, presumably by moving air around in various sinuses. The neck is unusually mobile because the cervical vertebrae are not fused, and Belugas readily turn or nod their heads. The beak is short and broad, with a cleft upper lip and a labile mouth that can be puckered. The belly and sides may be lumpy, with folds and creases of fat. There is no dorsal fin, but there is a narrow ridge on the back where a dorsal fin would otherwise be. The broad flippers are upcurled at the tips in large males. The flukes become increasingly ornate as the animal ages, and those of mature adults are strongly convex on the rear margin. There are eight to nine pairs of peg-like teeth in both the upper and lower jaws, sometimes worn down to the gum in older adults.

Young Belugas are evenly gray. They lighten as they age and eventually become completely white except for dark pigment on the dorsal ridge and along the edges of the flukes and flippers. The white skin of adults can sometimes have a yellowish cast when they begin congregating in estuaries in summer, but this disappears after they molt.

RANGE AND HABITAT Belugas have an essentially circumpolar distribution in the Northern Hemisphere, centered mainly between 50°N and 80°N. Nearly 30 stocks are provisionally recognized for management purposes. Stocks are defined primarily on the basis of summering grounds, most of which are centered on estuaries where the animals molt. Belugas exhibit a high degree of philopatry, or loyalty to a site, and individuals (females in particular) tend to return, year after year, to the estuary visited by their mother in the year of their birth. In fall, Belugas are driven away from bays and estuaries by ice, and they winter primarily in polynyas, near the edges of pack ice, or in areas of shifting, unconsolidated ice. They appear to be equally at home in shallow river mouths, where they may become stranded between tides, and in deep submarine



BELUGA
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH		
LENGTH	4'11"–5'3" (1.5–1.6 m)	
WEIGHT	176–220 lb (80–100 kg)	
MAXIMUM MEASUREMENTS		
LENGTH	MALE	14–16' (4.2–4.9 m)
	FEMALE	13–14' (3.9–4.3 m)
WEIGHT	MALE	2,400–3,500 lb (1,100–1,600 kg)
	FEMALE	1,500–2,600 lb (700–1,200 kg)
LIFE SPAN		
At least 25 years, possibly more than 50		

■ RANGE
? POSSIBLE RANGE
● EXTRALIMITAL RECORDS

trenches, where they dive to depths in excess of 2,600 feet (800 m).

SIMILAR SPECIES The Narwhal is the species most likely to be confused with the Beluga, but mainly in latitudes north of about 65°N. Adult male Narwhals usually have a spiraled tusk jutting forward from the upper lip, making them reasonably easy to distinguish, and the mottled or spotted skin of adult Narwhals is in contrast to the even gray or white of Belugas. In the Arctic and Subarctic at times, particularly from an aerial perspective, the silvery flashes from a shoal of Harp Seals may superficially resemble a pod of young Belugas rolling at the surface. The tails of seals, however, move from side to side rather than vertically, and Harp Seals tend to be quicker, more active, and inclined to remain at or just below the surface. Whitecaps, small bits of floating ice, and even seabirds can be difficult to distinguish from Belugas at a distance. One experienced researcher describes a Beluga at ½ to 1¼ miles (1–2 km) away as a white spot that appears, grows, shrinks, and disappears, remaining in view for about three seconds.

BEHAVIOR Belugas are highly social, occurring in close-knit pods, often of the same sex and age class. Groups of large males, numbering several hundred, are observed in summer, as are smaller groups consisting of mothers and their dependent calves. Aggregations of Belugas in estuaries can build to thousands of animals when undisturbed by hunting. Belugas have a diverse vocal repertoire that encompasses trills, squawks, bell-like sounds, sharp reports (possibly caused by jaw clapping), and a sound like that made by rusty gate hinges. Bill Schevill, a pioneer in the field of cetacean bioacoustics, described their "high-pitched resonant whistles and squeals, varied with ticking and clucking sounds slightly reminiscent of a string orchestra tuning up, as well as mewing and occasional chirps." Sometimes their calls reminded him of a crowd of children shouting in the distance. The most serious hazards for wild Belugas, apart from human hunters, are Killer Whales and Polar Bears. The bears quickly converge on areas where Belugas are ice-entrapped, taking a heavy toll by swiping at the animals with their powerful paws and dragging them onto the ice.

ABOVE: *The Beluga's melon is bulbous and malleable. This animal's short, broad beak is well demarcated from the melon. Its skin appears to be in transition from gray to white as occurs as Belugas approach maturity.*
RIGHT: *The all-gray Beluga calves are easily distinguishable from the essentially all-white adults.*

A closely spaced pod of five adult Belugas moves along the coast of Alaska in pack ice. Adaptation to living in an icy environment has allowed the Beluga to disperse throughout most of the Arctic and Subarctic.

REPRODUCTION The timing of reproductive events varies by region. In general, conception takes place in late winter or spring when the animals are least accessible for observation (late February to mid-April in Alaska; May in eastern Canada and West Greenland). Credible estimates of the gestation period range from somewhat less than a year to 14½ months. Young Belugas are nursed for two years and may continue to associate with their mothers for a considerable time thereafter. The calving interval probably averages three years.

FOOD AND FORAGING The diets of Belugas vary according to regional and seasonal prey availability. Stomach contents of individuals from various regions demonstrate that the species' overall diet includes a great variety of organisms: fish (from salmon to arctic cod to herring and capelin), cephalopods (squid and octopuses), crustaceans (shrimps and crabs), marine worms, and even large zooplankton. Many prey items are bottom-dwelling organisms. This probably explains why many dives (monitored with time-depth recorders) have a "square" profile, characterized by a steep and continuous descent and ascent, with a distinct bottom phase in between. The whales are almost certainly foraging near the seabed, at depths of at least 1,000 feet (300 m). The Beluga's puckered lips serve to create suction as the animal forages (and also enable Belugas to shoot streams of water at oceanarium spectators).

STATUS AND CONSERVATION Although there are well over 100,000 Belugas in the circumpolar Arctic today, their aggregate abundance was much greater in the past, before commercial hunting decimated some groups. Among the more robust populations today are those in the Beaufort Sea (40,000), the eastern High Arctic of Canada (28,000), western Hudson Bay (25,000), and the eastern Bering Sea (18,000). The whales in these four areas are hunted locally, but the removal rates are thought to be sustainable. In contrast, a number of other populations are in great peril and should not be, but are, still hunted. These include those in Cook Inlet, Ungava Bay, and some parts of southeastern Baffin Island and West Greenland. The animals in the St. Lawrence River have high contaminant burdens in their bodies and high cancer rates. Some formerly important Beluga estuaries are now infested with motorboats and hunters, rendering them unsuitable to support large aggregations of the whales. Hunt management is the most critical immediate imperative for Beluga conservation.

Bowhead Whale

Balaena mysticetus
Linnaeus, 1758

- LARGE AND ROTUND, WITH BROAD BACK AND NO DORSAL FIN
- ALL BLACK EXCEPT FOR WHITE CHIN PATCH
- HEAD ONE-THIRD BODY LENGTH, WITH BOWED MOUTHLINE
- PROMINENT "CROWN" AT BLOWHOLES, WITH DEPRESSION BEHIND
- OFTEN RAISES FLUKES WHILE DIVING
- V-SHAPED BLOW
- CIRCUMPOLAR IN HIGH LATITUDES OF NORTHERN HEMISPHERE

JUVENILE

MATURE MALE

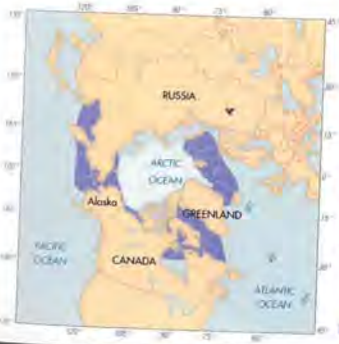
Of all large whales, the Bowhead is the most adapted to life in cold water, with a layer of blubber up to 1½ feet (50 cm) thick and a huge head that it uses to break through thick ice. Closely associated with sea ice through much of the year, the Bowhead Whale is found throughout arctic and subarctic areas in the Northern Hemisphere. Whalers hunted this species extensively until the early 20th century. The scientific name translates to "whale" (from the Latin words *balaena* and *cetus*) and "mustached" (from the Greek *mustakos*), referring to the very long baleen. The Bowhead is also known as the Greenland Right Whale.

DESCRIPTION The Bowhead Whale is large and very robust, with a huge head that in adults is fully one-third of its body length. The body is black, with a white chin patch that often has a line of black spots. The mouthline is strongly arched, and the rostrum very narrow. Baleen plates, numbering 230 to 360 on either side of the mouth, are black, narrow, and up to 14 feet (4.3 m) long. There is a peaked ridge, or "crown," before the blowholes and a notable depression behind them, particularly in adults. Bowheads have no dorsal fin and broad, triangular flukes with smooth margins, which they often raise during deep dives. Their blow is V-shaped when seen from the front or from behind.

RANGE AND HABITAT Bowhead Whales have a circumpolar distribution in high latitudes in the Northern Hemisphere. They are closely associated with ice for much of the year, wintering at the southern limit of the pack ice or in polynyas (large, semi-stable open areas of water within the ice), then moving northward as the sea ice breaks up and recedes during spring. A reverse movement occurs as ice cover spreads southward in autumn. There are five recognized populations of Bowheads. The largest winters in the Bering Sea and migrates northward into the Beaufort and Chukchi Seas in the spring. A second population summers along the western and perhaps northern portion of the Sea of Okhotsk, notably around the Shantar Islands; its wintering ground is largely unknown, but it is likely that most remain in the Sea of Okhotsk year-round. Three other populations occur in the Atlantic: in Davis Strait and Baffin Bay, Hudson Bay and Foxe Basin, and the area of Spitsbergen Island and the Barents Sea.

SIMILAR SPECIES The North Atlantic and North Pacific Right Whales, the only whales that might be confused with the Bowhead, are easy to distinguish by the callosities on their heads. Unlike Bowheads, northern right whales are frequently white or marbled underneath, and their baleen, while sometimes similar in length, is never longer than 9 feet (2.7 m). They occur rarely in the extreme southern portion of the Bowhead's range and are unlikely to be associated with ice.

BEHAVIOR Bowhead Whales show little stability in their social organization beyond the mother-calf pair bond. Most other associations between individuals last only for hours or at most a few days. However, given that Bowhead vocalizations can be easily heard over several miles, the



BOWHEAD WHALE
FAMILY BALAENIDAE

MEASUREMENTS AT BIRTH

LENGTH	13-15' (4–4.5 m)
WEIGHT	2,000 lb (900 kg)

MAXIMUM MEASUREMENTS

LENGTH	65' (19.8 m)
WEIGHT	About 200,000 lb (90,000 kg)

LIFE SPAN

Recent research suggests that this species may live considerably longer than 100 years

existence of some loose herd structure at times is possible. It appears likely that some Bowhead sounds function as primitive echolocation, as vocalizing Bowheads have been observed to alter their course around icebergs and other obstructions well before they would have been able to detect them visually. Bowheads are adapted for traveling long distances under ice. Their massive heads can reportedly break through ice up to 6 feet (1.8 m) thick. Both the migration and the distribution of Bowheads during the summer feeding season appear to be somewhat segregated by age and sex. Mothers and calves are generally the last to migrate in spring, and juveniles and adults often feed in different regions. Breaching and lobtailing are commonly observed in this species, although the function of these behaviors is unclear. Virtually nothing is known about the behavior of Bowheads during late fall and winter, when ice conditions and arctic darkness make observations impossible.

REPRODUCTION Females give birth every three to four years. The gestation period has never been confirmed, but the best data suggest it lasts 13 to 14 months, with most calves born during the spring migration north. Weaning probably occurs when calves are 9 to 12 months old. Most conceptions are thought to occur in late winter or early spring, although mating behavior has been observed at other times of the year. Due to the male's unusually large testes, the mating system of the Bowhead Whale is thought to be based in part on sperm competition, involving a female mating with multiple males. Good evidence exists that, like Humpbacks, Bowhead males produce songs that may serve to advertise for females. These vocalizations are heard primarily in spring.

OPPOSITE TOP: *A Bowhead dives, showing its broad triangular tail.* **OPPOSITE BOTTOM:** *Two Bowhead Whales surface next to ice floes. The prominent white chin patch is an identifying feature of these whales.* **LEFT:** *A Bowhead raises its head above the surface in the open water of an ice lead.*

FOOD AND FORAGING Like right whales, Bowhead Whales are skim feeders; however, their diet is much more varied. Their primary prey are copepods and krill, and they also eat a wide variety of other invertebrates. More than 60 prey species have been identified in the stomachs of Bowheads killed by the Inuit hunt in Alaska. Bowheads are usually solitary while foraging, although they occasionally echelon feed together.

STATUS AND CONSERVATION Like the right whales, the Bowhead was the target of intensive whaling in the pre-modern era. Whaling for Bowheads began in the North Atlantic in the 16th century, with thousands of animals killed in waters from Spitsbergen Island to Labrador. The Bering-Chukchi-Beaufort population was first hunted in the mid-19th century, and the Sea of Okhotsk population was exploited shortly thereafter. Of the five populations recognized today, all but one remain highly endangered. The exception is the Bering-Chukchi-Beaufort population, estimated at more than 8,000 animals and steadily increasing despite continued hunting by Inuit. The Spitsbergen population is believed to be close to extinction, while the populations in Hudson Bay–Foxe Basin and Davis Strait–Baffin Bay may number a few hundred animals. The size of the Okhotsk Sea population is unknown but is probably at most a few hundred due to exploitation by the Soviet Union that continued into the 1960s. With the exception of the strictly managed Inuit hunt in Alaska, Bowheads are protected throughout their range.

Killer Whale

Orcinus orca
(Linnaeus, 1758)

- TALL, ERECT DORSAL FIN, MORE PROMINENT IN ADULT MALE
- LARGE ROUNDED FLIPPERS
- DISTINCTIVE BLACK-AND-WHITE COLOR PATTERN
- LARGE SIZE RELATIVE TO OTHER DOLPHINS
- COSMOPOLITAN DISTRIBUTION

The Killer Whale's exposure on television, in movies, and at oceanariums has made the species an icon. As recently as the 1960s, Killer Whales, also known as Orcas, were feared and persecuted; however, after a few individuals were brought into captivity and trained, the public's view of them became transformed. Today these whales are much loved. Killer Whales are among the best-known cetaceans, thanks mainly to the work of researchers based on the west coast of North America, who for more than three decades have studied the pods off Washington, British Columbia, and Alaska. The world population of Killer Whales seems to consist of specialized subpopulations, each adapted to live off the resources available within its home range. In this sense, Killer Whales are much like wolves. Some scientists believe that differences in morphology, genetics, ecology, and behavior among different groups of Killer Whales are a sufficient basis for establishing different races, subspecies, and perhaps even species.

DESCRIPTION The Killer Whale's body is extremely robust; it is the largest delphinid. The head is conical and lacks a well-defined beak. The dorsal fin, situated at midback, is large, prominent, and highly variable in shape: falcate in females and juveniles, erect and almost spike-like in adult males. On males, the dorsal fin can reach a height of 3 to 6 feet (1–1.8 m). The flippers are large, broad, and rounded, very different from the typically sickle-shaped flippers of most delphinids. There are 10 to 14 pairs of large pointed teeth in both the upper and lower jaws.

The color pattern consists of highly contrasting areas of black and white. The white ventral zone, continuous from lower jaw to anus, narrows between the all-black flippers and branches behind the umbilicus. The ventral surface of the flukes and adjacent portion of the caudal peduncle are also white. The back and sides are black, except for white patches on the flanks that rise from the uro-genital region and prominent oval white patches slightly above and behind the eyes. There is a highly variable, gray to white saddle marking on the back behind the dorsal fin.

RANGE AND HABITAT Considered the most widespread cetacean, the Killer Whale is truly cosmopolitan and is not limited by such habitat features as water temperature, or depth. It occurs in highest densities at high latitudes, especially in areas with an abundance of prey. Its movements generally appear to track those of favored prey species or to take advantage of pulses in prey abundance or vulnerability, such as during times and in areas of fish spawning and seal pupping.

In the Antarctic during summer, most Killer Whales position themselves near the ice edge and in channels within the pack ice, where they prey on baleen whales, penguins, and seals. It is uncertain how far, or where, they migrate. Some may remain in antarctic waters year-round. In the Arctic, Killer Whales rarely move close along or into the pack ice. Researchers studying Killer Whales in Washington and British Columbia have identified "resident" and "transient" pods,

KILLER WHALE
FAMILY DELPHINIDAE

MEASUREMENTS AT BIRTH

LENGTH	7'3"–8'6" (2.2–2.6 m)
WEIGHT	About 350 lb (160 kg)

MAXIMUM MEASUREMENTS

LENGTH	**MALE**	30' (9 m)
	FEMALE	26' (7.9 m)
WEIGHT	**MALE**	At least 12,000 lb (5,600 kg)
	FEMALE	At least 8,400 lb (3,800 kg)

LIFE SPAN

MALE 50–60 years
FEMALE 80–90 years

Killer Whales evoke strong responses from people in part because they are at once large, intimidating, and playful. Here a young breaching animal displays the species' broad flippers and white ventral markings, while a larger animal in the foreground shows the impressive dorsal fin and the distinctive light "saddle" marking on the back immediately behind the fin.

although both types of pod are present year-round. Some individuals occupy very large ranges. For example, photo-identification studies have shown that some Killer Whales move between Alaska and California. (The range map for this species shows areas where Killer Whales are known to occur but probably underrepresents the total range of the species.)

SIMILAR SPECIES The Killer Whale is among the easiest of the cetaceans to identify. However, at a distance, the relatively prominent dorsal fins of the False Killer Whale and Risso's Dolphin can cause confusion. Both species overlap with Killer Whales in tropical and temperate waters.

BEHAVIOR The basic social unit of resident Killer Whales in Washington and British Columbia is the matrilineal group, consisting of two to four generations of two to nine related individuals. Matrilineal groups are stable over long periods, and all members may contribute to calf rearing. A number of groups that spend much of their time together constitute a pod. The largest resident pod in the area of Washington and British Columbia contains close to 60 individuals. Resident pods greet one another by facing off in two tight lines, then mingling in a relaxed manner, as if to reaffirm their social bonds. While adult females tend to be associated with one or more pods, adult males are sometimes solitary.

Killer Whales often breach, spyhop, and slap the surface with their flukes or flippers. They exhibit varied responses to vessels, ranging from indifference to curiosity. Mass strandings occur occasionally, and pods sometimes become trapped in tidal ponds or inlets. Wind-blown or fast-forming ice can be a hazard for Killer Whales in the Arctic and Antarctic, forcing them to remain in small pools of open water for prolonged periods.

REPRODUCTION In the resident population off Washington and British Columbia, calving occurs year-round, with a peak between autumn and spring. The average calving interval is five years. Females usually stop reproducing after about 40 years of age. Studies of whales in captivity suggest that gestation lasts 15 to 18 months. Although Killer Whales begin eating solid food

RIGHT: *These spyhopping Killer Whales belong to one of the populations that visit or reside in inshore waters of Washington state and British Columbia.*
BELOW: *This group of Killer Whales includes three adult males, each of them readily identifiable by the tall, triangular dorsal fin. The animals in the center of the group are either females or juvenile males.*

at a very young age, they continue to nurse for at least a year and may not be fully weaned until close to two years of age.

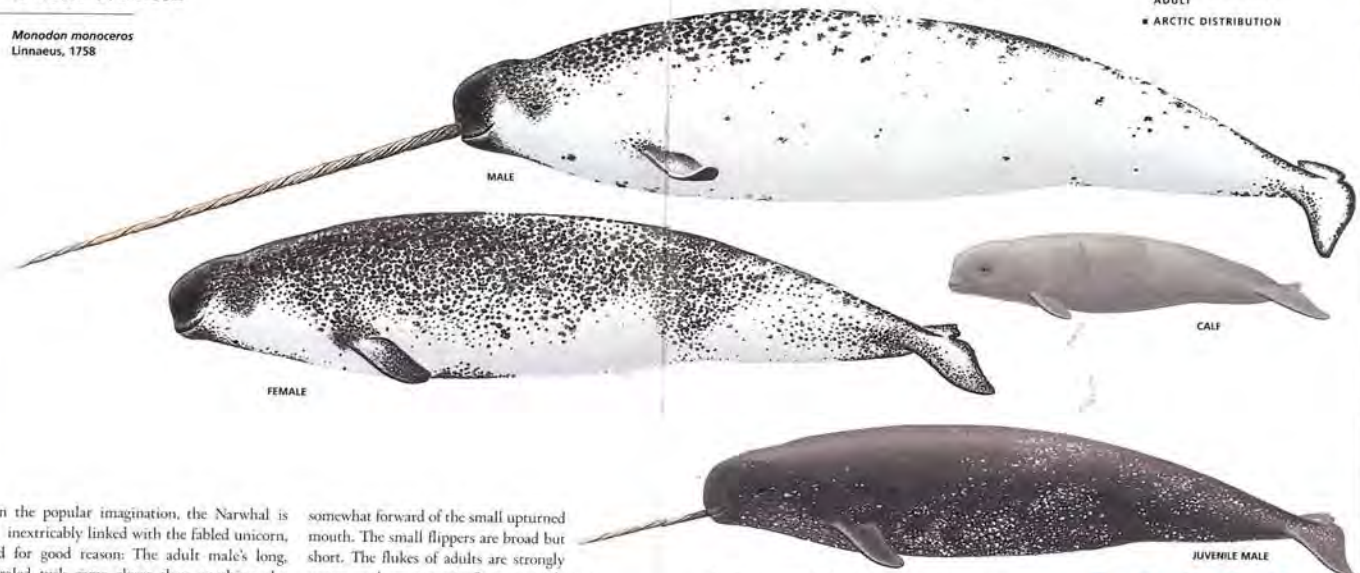
FOOD AND FORAGING Killer Whales eat a diet ranging from small schooling fish and squid to large baleen and sperm whales. Their prey items include sea turtles, otters, sirenians, sharks, rays, and even deer or moose, which they catch swimming across channels. Pods tend to specialize. For example, some depend largely on salmon, tuna, or herring, while others patrol pinniped haulouts or follow migratory whale populations, much as wolves follow caribou herds. Killer Whales obviously need to use cooperative hunting to harass and subdue large prey items, but they also cooperate to consolidate and maintain tight balls of baitfish, taking turns slicing through the schools to feed. Killer Whales also steal fish from longlines, scavenge on discarded fishery bycatch, and selectively eat the tongues of baleen whales. Prey may be strongly influenced by their fear of Killer Whales; pinnipeds flee from the water onto land or ice and whales and dolphins move into nearshore shallows or hide in cracks in pack ice.

STATUS AND CONSERVATION While as a species the Killer Whale is not endangered, whaling or live-capture operations have depleted some regional populations. Resident and transient populations off Washington and British Columbia number only in the low hundreds, and are threatened by pollution, heavy ship traffic, and possibly reduced prey abundance. There is concern that intensive whale-watching operations may influence the behavior of Killer Whales, and that the loud "seal-scarers" used to protect salmon pens from predation by pinnipeds may be driving Killer Whales away from their preferred inshore resting and foraging waters. About 8,500 Killer Whales are thought to occur in the eastern tropical Pacific, at least 850 in Alaskan waters, possibly close to 2,000 off Japan, and about 80,000 in the Antarctic during summer. Estimates from most other areas are in the hundreds or low thousands. Whalers in Japan, Indonesia, Greenland, and the West Indies continue to hunt Killer Whales; while the whales are killed in only small numbers, the effects of hunting on local populations could be substantial.

Narwhal

Monodon monoceros
Linnaeus, 1758

- LONG TUSK ON ADULT MALES
- SMALL ROUNDED HEAD WITH NO BEAK
- NO DORSAL FIN
- SPOTTED, BLACK-AND-WHITE DORSAL COLORATION IN ADULT
- ARCTIC DISTRIBUTION

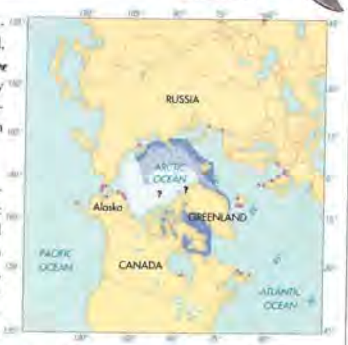


In the popular imagination, the Narwhal is inextricably linked with the fabled unicorn, and for good reason: The adult male's long, spiraled tusk came closer than anything else in nature to "proving" the unicorn's existence. In fact, from the Middle Ages onward, traders and chemists conspired to keep the existence of the Narwhal a secret, while selling its tusks as "unicorn horns" for immense profit. Although it is no longer linked to the mythical horned horse, the Narwhal is still a compelling creature because of the remoteness and harshness of its arctic environment as well as its unusual appearance. Thanks to the efforts of native local people and adventurous scientists equipped with powerful new high-tech tools, we are finally beginning to learn some of the details about the lives of Narwhals, even during the dark polar winter.

DESCRIPTION The Narwhal has a short rounded head with no beak. The melon is bluff, protruding somewhat forward of the small upturned mouth. The small flippers are broad but short. The flukes of adults are strongly convex on the rear margin; from an aerial perspective, they are reminiscent of butterfly wings. Like Belugas, Narwhals have no dorsal fin but rather a low fleshy ridge along the posterior half of the back. All Narwhals lack functional teeth inside the mouth, and most females remain essentially toothless throughout life. In males (and rarely females), the left of two upper-jaw teeth erupts through the lip at two or three years of age and keeps growing. The erupted portion of this tusk can be up to 9 feet (2.7 m) long, and the entire tusk can weigh more than 22 pounds (10 kg). In most cases, the surface of the tusk has a leftward spiral, but the axis is straight. Occasionally even the axis itself is twisted. The right tooth sometimes also erupts so that the animal is "double-tusked."

Adult Narwhals are spotted black and white on the back and upper sides. Old individuals can be almost completely white, with black areas limited to the center of the back, the top of the head, and the edges of the appendages. Newborn Narwhals are light gray but become almost black by the time they are weaned. Thereafter, they become mottled as white areas begin to appear on the belly and sides.

RANGE AND HABITAT Narwhals have a discontinuous arctic distribution. They are most abundant in deep waters that branch northward from the North Atlantic basin, especially Hudson Strait, northwestern Hudson Bay, Foxe Basin, Davis Strait, Baffin Bay, and Lancaster Sound. Another center of distribution is in the Greenland Sea, with small groups also occurring in parts of the northern Barents Sea. Their migrations are tuned to the formation and movement



NARWHAL
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH
LENGTH 5'3" (1.6 m)
WEIGHT 176 lb (80 kg)

MAXIMUM MEASUREMENTS
LENGTH **MALE** 15'6" (4.7 m)
FEMALE 14' (4.2 m)
WEIGHT **MALE** 3,500 lb (1,600 kg)
FEMALE 2,200 lb (1,000 kg)

LIFE SPAN
At least 25 years, possibly 50

Narwhals occasionally lift their flukes as they dive. The ornately curved flukes are distinctive in both color and shape.

of sea ice. As the ice disintegrates and breaks up in spring, Narwhals follow the receding edge of the pack ice and use small cracks and melt holes to penetrate deep sounds and fjords as quickly as possible. They reside in these areas throughout the summer and early fall. As the ice cover re-forms, they head for offshore wintering areas where the ice is constantly in motion, allowing them to find breathing space between the floes.

SIMILAR SPECIES The Beluga is the only species that might be confused with the Narwhal, primarily with females and juveniles since the tusk of adult male Narwhals is so distinctive. Belugas are either solid gray or white, never black, mottled, or spotted. Both species are fairly gregarious, and usually at least a few individuals within a group have readily identifiable features. Belugas can occur in all areas inhabited by Narwhals, and occasionally the two species are seen together. However, they normally do not form mixed groups or schools; both species tend to form large single-species concentrations, particularly in summer.

BEHAVIOR Narwhals often form large aggregations of several hundred animals during summer. Such aggregations, however, consist of smaller, fairly close-knit groups of a few up to about 20 individuals. These groups are typically homogeneous, consisting of animals of the same sex or a single age class. In winter while distributed in the pack ice, Narwhals seem to be more scattered and solitary, perhaps owing to the patchiness of cracks and holes in the ice. The presence of scars and wounds in the head region, and the high incidence of broken tusks, suggest that adult males fight one another. Such fighting could play a role in establishing dominance and thus access to mating opportunities. While Narwhals have been seen apparently crossing tusks above the surface, there is no concrete evidence that they fence with them. Polar Bears are known to kill Narwhals that are trapped in small pools of open water, and Killer Whales prey on them in their inshore summering areas. Although they do not mass strand like pilot whales, Narwhals are subject to catastrophic mortality from entrapment by wind-driven or fast-forming ice. The frequency and scale of such mortality are especially high in the Disko Bay region of West Greenland.

REPRODUCTION Narwhals mate during late winter and spring (peaking in April), when the animals are generally inaccessible for observation. Gestation lasts about 15 months, and most calves are born in summer (July–August, peaking around the first of August) when the animals are in fjords. Lactation and nursing lasts for at least a year, so the calving interval is at least two years and probably averages three.

FOOD AND FORAGING Narwhals are deep divers. They forage in the entire water column, taking pelagic fish (especially arctic cod), squid, and shrimp, as well as bottom-dwelling species such as Greenland halibut. Dives can last as long

As they migrate toward their summering areas in deep arctic fjords, Narwhals take advantage of cracks and leads in the pack ice, crowding one another for breathing space. The two individuals in the foreground appear to be young males, their tusks projecting forward for only a foot or two, and their dark bodies only beginning to whiten.

as 20 minutes and reach depths of more than 3,300 feet (1,000 m). Narwhals apparently suck prey into their mouth and swallow it whole. They do not use the tusk to spear fish.

STATUS AND CONSERVATION Narwhals have long been hunted by native peoples for food, oil, and ivory. The skin (called "maktaq," variously spelled) is considered a delicacy. Commercial whalers hunted Narwhals but generally only on a casual basis, as Bowhead Whales were their preferred quarry in the Arctic. For a brief period in the early 20th century, the Hudson's Bay Company purchased Narwhal skins and tusks for export (the former to be used to make soft leather gloves). Tusks continue to be profitable export items, and maktaq has high commercial value in northern towns in both Canada and Greenland. Population estimates based on aerial surveys are about 35,000 Narwhals in Baffin Bay, 1,400 in Hudson Strait, and 300 in Scoresby Sound (East Greenland). These numbers were not corrected to account for submerged animals, and the true range-wide abundance may be greater than 50,000. The principal known threat to Narwhal populations is hunting, particularly since it is now facilitated by fast motorized boats and high-powered rifles.

This aerial view of four Narwhals, taken in the eastern Canadian Arctic, shows many of the species' distinctive features, including the long spiraled tusk, the small rounded head, the mottled, black-and-white coloration, and the absence of a dorsal fin. The low dorsal ridge appears as a dark line along the middle of the back of the older whiter animals.

LEFT: *Largha Seals, also called Spotted Seals, are similar in body shape, size, and coloration to Harbor Seals, but Largha Seals haul out and breed principally on pack ice, compared to the terrestrial habitats preferred by Harbor Seals.* **RIGHT:** *Newborn Largha Seals also have a thick white lanugo pelage, which is shed when they are about three to four months old, revealing the adult spotted color pattern.*

in the open ocean, their behavior is virtually unstudied. They may occur in well-spaced family groups on the sea ice during the breeding season in spring.

REPRODUCTION Largha Seals are thought to be seasonally monogamous. During the breeding season, they are most often seen well spaced out on the ice in triads consisting of an adult female, her pup, and an adult male. Females give birth on the surface of ice floes from January through mid-April, with a peak in mid- to late March. Males are thought to join a female and her pup about a week after pupping, and the group remains together until the pup is weaned at three to four weeks old, at which time mating occurs and the male leaves the group. This system limits the mating opportunities of males during a breeding season; however, males that mate early in the season may later find an unattended female-pup pair or may displace another male from a triad. Mating evidently takes place in the water.

FOOD AND FORAGING Adults and juveniles eat a variety of schooling fish (pollock, capelin, arctic cod, and herring), epibenthic fish (especially flounder, halibut, and sculpin), and crabs and octopus at depths of up to 1,000 feet (300 m). Weaned pups apparently mostly eat amphipods, krill, and other small crustaceans.

STATUS AND CONSERVATION Native peoples along the eastern Russian coast and in Alaska have traditionally killed small numbers of Largha Seals for subsistence. The Soviet Union made some commercial harvests from the 1930s through the 1980s in the Sea of Okhotsk and the western Bering Sea, and Japan also commercially hunted these seals in the Sea of Okhotsk at times. Largha Seals occasionally drown in fishing nets set in coastal waters of northern Hokkaido, Japan. Population abundance is poorly known but has been estimated at around 350,000 to 400,000, with about half of the seals living in the Bering and Chukchi Seas.

Ringed Seal

Pusa hispida **(Schreber, 1775)**

- DARK DORSAL PELAGE WITH SCATTERED, IRREGULAR LIGHT RINGS AND DARK BACKGROUND
- SMALLEST TRUE SEAL NEXT TO BAIKAL SEAL
- EXCAVATES BIRTH LAIRS BENEATH ICE SURFACE
- DISTRIBUTION CLOSELY ASSOCIATED WITH LANDFAST AND PACK ICE
- WIDELY DISPERSED IN ARCTIC BASIN AND BERING, OKHOTSK, JAPAN, AND BALTIC SEAS

The smallest and most common seals in the Arctic Ocean and the Bering and Baltic Seas, Ringed Seals have long been important prey for native inhabitants of the Arctic. They are also the top prey of Polar Bears, and during the breeding season, Ringed Seals excavate birth lairs in ice and snow to protect themselves against this predation. The Baikal Seal is the only other pinniped known to use such structures for giving birth and raising pups. Scientists recognize five subspecies of the Ringed Seal, including two freshwater populations. The Ringed Seal was formerly included in the genus *Phoca* along with the Baikal and Caspian Seals. However, taxonomists have recently reinstated these three species to the genus *Pusa*, which is derived from the common name for the Ringed Seal used by the Inuit of Greenland and various eastern North Atlantic cultures. The specific name is derived from the Latin word *hispidus*, meaning "hairy" or "bristly," and refers to the adult pelage, which is often stiffer than that of other phocid pinnipeds. The common name refers to the scattered irregular rings on the pelage.

DESCRIPTION The Ringed Seal has a small plump body and a small head. The snout is narrow, short, and cat-like. The flippers are small, with short slender claws on the hindflippers and robust claws on the foreflippers that may be more than an inch long. There are nine pairs of teeth in the upper jaw and eight pairs in the lower jaw.

The pelage of adults is dark dorsally with scattered irregular rings, and lighter and less ringed ventrally. Newborn pups have a woolly, white lanugo coat that they shed at about six to eight weeks old to reveal an unspotted pelage that is uniformly dark silver or gray dorsally and light silver ventrally. The ringed pattern develops at the first annual molt when seals are a little more than one year old.

RANGE AND HABITAT Ringed Seals have a circumpolar distribution throughout the Arctic Ocean, Hudson Bay, and Baltic and Bering Seas. They are closely associated with sea ice. In summer they often occur along the receding ice edge and farther north in denser pack ice. Five subspecies are recognized. The most widely dispersed form, *Pusa hispida hispida*, occurs in the Arctic Basin. *P. h. ochotensis* occurs in the Sea of Okhotsk and the Sea of Japan, and *P. h. botnica* occurs in the Baltic Sea. Freshwater populations

RINGED SEAL

FAMILY PHOCIDAE

MEASUREMENTS AT BIRTH

LENGTH 26" (60–65 cm)
WEIGHT 9–11 lb (4–5 kg)

MAXIMUM MEASUREMENTS

LENGTH 5'3" (1.6 m)
WEIGHT 240 lb (110 kg)

LIFE SPAN

25–30 years

■ RANGE
? POSSIBLE RANGE
■ VAGRANTS

include *P. h. saimensis* in Lake Saimaa in eastern Finland and *P. h. lagodensis* in Lake Ladoga, Russia. Vagrants from the marine populations have ranged as far south as Portugal in the Atlantic Ocean and California in the Pacific.

SIMILAR SPECIES Harbor, Harp, Hooded, Gray, Bearded, Ribbon, and Largha Seals may occupy similar habitats in various parts of the Ringed Seal's range. All but Harbor and Largha Seals can be readily distinguished by their body and head morphology and pelage patterns. Largha Seals, which may overlap in the Bering, Okhotsk, and Japan Seas, have a spotted rather than a ringed pelage pattern and are larger but more slender than Ringed Seals, with relatively longer, wider snouts. Harbor Seals prefer ice-free habitats and are rarely seen in ice.

BEHAVIOR Though there are areas of high density of Ringed Seals through the Arctic, these seals do not aggregate in large groups. Rather, they are largely solitary and space out from one another by hundreds of yards or more. During the breeding season, triads of an adult female, her pup, and an adult male form short-term family groups. These groups are not easily observed, however, as the seals remain in lairs in the ice and snow excavated by the females for pupping and nursing. The excavation of lairs in and under sea and lake ice is unique to Ringed Seals and is evidently an adaptation for escaping predation by Polar Bears. Some lairs are quite complex, with several chambers. Females evidently leave pups in the lairs for short periods while they forage nearby. Throughout winter, Ringed Seals maintain breathing holes by chewing away newly formed ice. Individuals may favor particular breathing holes, perhaps excluding other seals from loosely associated underwater territories. Ringed Seals molt in June and July; while molting, they spend more time basking on the surface of the ice than in other seasons. Ringed Seals are the primary prey of Polar Bears, and are also occasionally eaten by Walruses and Killer Whales.

REPRODUCTION The breeding system of the Ringed Seal is thought to be either mildly polygynous or serially monogamous, but is not well known because of the difficulty in finding and observing seals during the breeding season. Females excavate lairs in the pressure ridges or accumulated snow on sea or lake ice, and in Lake Saimaa in snowdrifts along the shoreline. They give birth in March and April in most areas, a little earlier in the Baltic Sea. Pups are weaned and mating occurs between April and May. Males evidently patrol under the ice searching for receptive females. They may stay with a female for several days until they mate, and then return to the water to patrol for another potential mate.

FOOD AND FORAGING When feeding along the sea-ice edge in summer, Ringed Seals eat mostly polar cod, even though the potential prey biomass there is dominated by pelagic crustaceans. The seals evidently selectively choose these prey, which represent about only 1 percent of the fish and crustacean biomass. In these areas, Ringed Seals eat smaller cod, evidently at shallower depths than the sympatric Harp Seals. Most dive depths for *P. h. hispida* are 35 to 150 feet (10–45 m) for sexually mature males, and 330 to 475 feet (100–145 m) for subadult males and postpartum females. Most dives last about 4 minutes for adult males and 7½ minutes for adult females. The longest dive recorded is about 23 minutes, although the seal may actually have been resting on the sea bottom rather than feeding.

STATUS AND CONSERVATION Ringed Seals have been key subsistence prey for native arctic peoples, who hunt them for food for humans and dogs as well as for skins to make clothing. Levels of PCBs are higher in seals taken by subsistence hunters in the European and Russian Arctic than in other arctic regions. These higher levels are thought to be due to continued use of PCBs in Russian electrical equipment. Though never completely surveyed, the species may number as many as 4 million. Ringed Seals in the Baltic Sea are considered to be at risk because of heavy pollution, which affects the seals' immune systems and reproductive success. Although about half of the Ringed Seals in Lake Saimaa breed in coastal areas located within national parks, poaching and threats associated with fisheries in other parts of the lake seriously threaten this small population.

OPPOSITE: *Ringed Seals have a robust body and small head and foreflippers. The dark pelage background with scattered light rings is characteristic of the species.* **RIGHT:** *Ringed Seals are the primary prey of Polar Bears and so are extremely wary when surfacing in their breathing holes, which may be staked out by patient, hungry bears. Ringed Seals maintain these breathing holes by abrading the ice with their canine teeth.*

Beluga

Delphinapterus leucas
(Pallas, 1776)

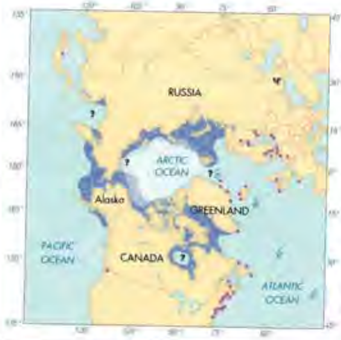
- **WHITE ADULT COLORATION**
- **ROUNDED, MALLEABLE MELON AND FLEXIBLE NECK**
- **SHORT BROAD BEAK WITH CLEFT UPPER LIP**
- **BROAD FLIPPERS AND ORNATELY SHAPED FLUKES**
- **LACK OF DORSAL FIN**
- **OCCURS ONLY IN HIGH LATITUDES OF NORTHERN HEMISPHERE**

Known by some early whalers as "sea canaries" because of their loquacious natures, these whales are abundant and widespread in the Arctic and Subarctic. For many centuries, Belugas, also known as White Whales, have been a staple of arctic societies, providing food, fuel oil, and even soft durable leather. They were among the first cetaceans to be brought into captivity. Their resilience and adaptability, stunning appearance, engaging disposition, and trainability have made them popular performers in oceanariums. Several areas where Belugas congregate have become whale-watching meccas, most notably eastern Canada's lower St. Lawrence River and the Churchill River estuary in western Hudson Bay. Over the past 15 years, there has been a flurry of research on the species, much of it involving satellite telemetry. These studies have shown that the Beluga has impressive diving abilities and is even more ice-adapted and abundant than was previously believed.

DESCRIPTION The Beluga has a rounded midsection that tapers toward the head and tail. Its torso is markedly rotund when the animal is well fed. The head is unlike that of any other cetacean, with a bulging melon that one researcher described as feeling like a balloon filled with warm lard. A Beluga is able to change the shape of its melon at will, presumably by moving air around in various sinuses. The neck is unusually mobile because the cervical vertebrae are not fused, and Belugas readily turn or nod their heads. The beak is short and broad, with a cleft upper lip and a labile mouth that can be puckered. The belly and sides may be lumpy, with folds and creases of fat. There is no dorsal fin, but there is a narrow ridge on the back where a dorsal fin would otherwise be. The broad flippers are upcurled at the tips in large males. The flukes become increasingly ornate as the animal ages, and those of mature adults are strongly convex on the rear margin. There are eight to nine pairs of peg-like teeth in both the upper and lower jaws, sometimes worn down to the gum in older adults.

Young Belugas are evenly gray. They lighten as they age and eventually become completely white except for dark pigment on the dorsal ridge and along the edges of the flukes and flippers. The white skin of adults can sometimes have a yellowish cast when they begin congregating in estuaries in summer, but this disappears after they molt.

RANGE AND HABITAT Belugas have an essentially circumpolar distribution in the Northern Hemisphere, centered mainly between 50°N and 80°N. Nearly 30 stocks are provisionally recognized for management purposes. Stocks are defined primarily on the basis of summering grounds, most of which are centered on estuaries where the animals molt. Belugas exhibit a high degree of philopatry, or loyalty to a site, and individuals (females in particular) tend to return, year after year, to the estuary visited by their mother in the year of their birth. In fall, Belugas are driven away from bays and estuaries by ice, and they winter primarily in polynyas, near the edges of pack ice, or in areas of shifting, unconsolidated ice. They appear to be equally at home in shallow river mouths, where they may become stranded between tides, and in deep submarine



BELUGA
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH		
LENGTH	4'11"–5'3" (1.5–1.6 m)	
WEIGHT	176–220 lb (80–100 kg)	
MAXIMUM MEASUREMENTS		
LENGTH	**MALE**	14–16' (4.2–4.9 m)
	FEMALE	13–14' (3.9–4.3 m)
WEIGHT	**MALE**	2,400–3,500 lb (1,100–1,600 kg)
	FEMALE	1,500–2,600 lb (700–1,200 kg)
LIFE SPAN		
At least 25 years, possibly more than 50		

■ **RANGE**
? POSSIBLE RANGE
● **EXTRALIMITAL RECORDS**

trenches, where they dive to depths in excess of 2,600 feet (800 m).

SIMILAR SPECIES The Narwhal is the species most likely to be confused with the Beluga, but mainly in latitudes north of about 65°N. Adult male Narwhals usually have a spiraled tusk jutting forward from the upper lip, making them reasonably easy to distinguish, and the mottled or spotted skin of adult Narwhals is in contrast to the even gray or white of Belugas. In the Arctic and Subarctic at times, particularly from an aerial perspective, the silvery flashes from a shoal of Harp Seals may superficially resemble a pod of young Belugas rolling at the surface. The tails of seals, however, move from side to side rather than vertically, and Harp Seals tend to be quicker, more active, and inclined to remain at or just below the surface. Whitecaps, small bits of floating ice, and even seabirds can be difficult to distinguish from Belugas at a distance. One experienced researcher describes a Beluga at ½ to 1¼ miles (1–2 km) away as a white spot that appears, grows, shrinks, and disappears, remaining in view for about three seconds.

BEHAVIOR Belugas are highly social, occurring in close-knit pods, often of the same sex and age class. Groups of large males, numbering several hundred, are observed in summer, as are smaller groups consisting of mothers and their dependent calves. Aggregations of Belugas in estuaries can build to thousands of animals when undisturbed by hunting. Belugas have a diverse vocal repertoire that encompasses trills, squawks, bell-like sounds, sharp reports (possibly caused by jaw clapping), and a sound like that made by rusty gate hinges. Bill Schevill, a pioneer in the field of cetacean bioacoustics, described their "high-pitched resonant whistles and squeals, varied with ticking and clucking sounds slightly reminiscent of a string orchestra tuning up, as well as mewing and occasional chirps." Sometimes their calls reminded him of a crowd of children shouting in the distance. The most serious hazards for wild Belugas, apart from human hunters, are Killer Whales and Polar Bears. The bears quickly converge on areas where Belugas are ice-entrapped, taking a heavy toll by swiping at the animals with their powerful paws and dragging them onto the ice.

ABOVE: *The Beluga's melon is bulbous and malleable. This animal's short, broad beak is well demarcated from the melon. Its skin appears to be in transition from gray to white as occurs as Belugas approach maturity.*
RIGHT: *The all-gray Beluga calves are easily distinguishable from the essentially all-white adults.*

A closely spaced pod of five adult Belugas moves along the coast of Alaska in pack ice. Adaptation to living in an icy environment has allowed the Beluga to disperse throughout most of the Arctic and Subarctic.

REPRODUCTION The timing of reproductive events varies by region. In general, conception takes place in late winter or spring when the animals are least accessible for observation (late February to mid-April in Alaska; May in eastern Canada and West Greenland). Credible estimates of the gestation period range from somewhat less than a year to 14½ months. Young Belugas are nursed for two years and may continue to associate with their mothers for a considerable time thereafter. The calving interval probably averages three years.

FOOD AND FORAGING The diets of Belugas vary according to regional and seasonal prey availability. Stomach contents of individuals from various regions demonstrate that the species' overall diet includes a great variety of organisms: fish (from salmon to arctic cod to herring and capelin), cephalopods (squid and octopuses), crustaceans (shrimps and crabs), marine worms, and even large zooplankton. Many prey items are bottom-dwelling organisms. This probably explains why many dives (monitored with time-depth recorders) have a "square" profile, characterized by a steep and continuous descent and ascent, with a distinct bottom phase in between. The whales are almost certainly foraging near the seabed, at depths of at least 1,000 feet (300 m). The Beluga's puckered lips serve to create suction as the animal forages (and also enable Belugas to shoot streams of water at oceanarium spectators).

STATUS AND CONSERVATION Although there are well over 100,000 Belugas in the circumpolar Arctic today, their aggregate abundance was much greater in the past, before commercial hunting decimated some groups. Among the more robust populations today are those in the Beaufort Sea (40,000), the eastern High Arctic of Canada (28,000), western Hudson Bay (25,000), and the eastern Bering Sea (18,000). The whales in these four areas are hunted locally, but the removal rates are thought to be sustainable. In contrast, a number of other populations are in great peril and should not be, but are, still hunted. These include those in Cook Inlet, Ungava Bay, and some parts of southeastern Baffin Island and West Greenland. The animals in the St. Lawrence River have high contaminant burdens in their bodies and high cancer rates. Some formerly important Beluga estuaries are now infested with motorboats and hunters, rendering them unsuitable to support large aggregations of the whales. Hunt management is the most critical immediate imperative for Beluga conservation.

Bowhead Whale

Balaena mysticetus
Linnaeus, 1758

- LARGE AND ROTUND, WITH BROAD BACK AND NO DORSAL FIN
- ALL BLACK EXCEPT FOR WHITE CHIN PATCH
- HEAD ONE-THIRD BODY LENGTH, WITH BOWED MOUTHLINE
- PROMINENT "CROWN" AT BLOWHOLES, WITH DEPRESSION BEHIND
- OFTEN RAISES FLUKES WHILE DIVING
- V-SHAPED BLOW
- CIRCUMPOLAR IN HIGH LATITUDES OF NORTHERN HEMISPHERE

MATURE MALE

JUVENILE

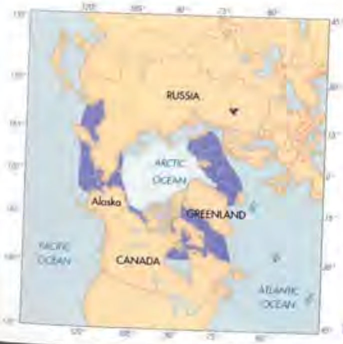
Of all large whales, the Bowhead is the most adapted to life in cold water, with a layer of blubber up to 1½ feet (50 cm) thick and a huge head that it uses to break through thick ice. Closely associated with sea ice through much of the year, the Bowhead Whale is found throughout arctic and subarctic areas in the Northern Hemisphere. Whalers hunted this species extensively until the early 20th century. The scientific name translates to "whale" (from the Latin words *balaena* and *cetus*) and "mustached" (from the Greek *mustakos*), referring to the very long baleen. The Bowhead is also known as the Greenland Right Whale.

DESCRIPTION The Bowhead Whale is large and very robust, with a huge head that in adults is fully one-third of its body length. The body is black, with a white chin patch that often has a line of black spots. The mouthline is strongly arched, and the rostrum very narrow. Baleen plates, numbering 230 to 360 on either side of the mouth, are black, narrow, and up to 14 feet (4.3 m) long. There is a peaked ridge, or "crown," before the blowholes and a notable depression behind them, particularly in adults. Bowheads have no dorsal fin and broad, triangular flukes with smooth margins, which they often raise during deep dives. Their blow is V-shaped when seen from the front or from behind.

RANGE AND HABITAT Bowhead Whales have a circumpolar distribution in high latitudes in the Northern Hemisphere. They are closely associated with ice for much of the year, wintering at the southern limit of the pack ice or in polynyas (large, semi-stable open areas of water within the ice), then moving northward as the sea ice breaks up and recedes during spring. A reverse movement occurs as ice cover spreads southward in autumn. There are five recognized populations of Bowheads. The largest winters in the Bering Sea and migrates northward into the Beaufort and Chukchi Seas in the spring. A second population summers along the western and perhaps northern portion of the Sea of Okhotsk, notably around the Shantar Islands; its wintering ground is largely unknown, but it is likely that most remain in the Sea of Okhotsk year-round. Three other populations occur in the Atlantic: in Davis Strait and Baffin Bay, Hudson Bay and Foxe Basin, and the area of Spitsbergen Island and the Barents Sea.

SIMILAR SPECIES The North Atlantic and North Pacific Right Whales, the only whales that might be confused with the Bowhead, are easy to distinguish by the callosities on their heads. Unlike Bowheads, northern right whales are frequently white or marbled underneath, and their baleen, while sometimes similar in length, is never longer than 9 feet (2.7 m). They occur rarely in the extreme southern portion of the Bowhead's range and are unlikely to be associated with ice.

BEHAVIOR Bowhead Whales show little stability in their social organization beyond the mother-calf pair bond. Most other associations between individuals last only for hours or at most a few days. However, given that Bowhead vocalizations can be easily heard over several miles, the



RANGE

BOWHEAD WHALE
FAMILY BALAENIDAE

MEASUREMENTS AT BIRTH
LENGTH 13-15' (4–4.5 m)
WEIGHT 2,000 lb (900 kg)

MAXIMUM MEASUREMENTS
LENGTH 65' (19.8 m)
WEIGHT About 200,000 lb (90,000 kg)

LIFE SPAN
Recent research suggests that this species may live considerably longer than 100 years

existence of some loose herd structure at times is possible. It appears likely that some Bowhead sounds function as primitive echolocation, as vocalizing Bowheads have been observed to alter their course around icebergs and other obstructions well before they would have been able to detect them visually. Bowheads are adapted for traveling long distances under ice. Their massive heads can reportedly break through ice up to 6 feet (1.8 m) thick. Both the migration and the distribution of Bowheads during the summer feeding season appear to be somewhat segregated by age and sex. Mothers and calves are generally the last to migrate in spring, and juveniles and adults often feed in different regions. Breaching and lobtailing are commonly observed in this species, although the function of these behaviors is unclear. Virtually nothing is known about the behavior of Bowheads during late fall and winter, when ice conditions and arctic darkness make observations impossible.

REPRODUCTION Females give birth every three to four years. The gestation period has never been confirmed, but the best data suggest it lasts 13 to 14 months, with most calves born during the spring migration north. Weaning probably occurs when calves are 9 to 12 months old. Most conceptions are thought to occur in late winter or early spring, although mating behavior has been observed at other times of the year. Due to the male's unusually large testes, the mating system of the Bowhead Whale is thought to be based in part on sperm competition, involving a female mating with multiple males. Good evidence exists that, like Humpbacks, Bowhead males produce songs that may serve to advertise for females. These vocalizations are heard primarily in spring.

OPPOSITE TOP: *A Bowhead dives, showing its broad triangular tail.* **OPPOSITE BOTTOM:** *Two Bowhead Whales surface next to ice floes. The prominent white chin patch is an identifying feature of these whales.* **LEFT:** *A Bowhead raises its head above the surface in the open water of an ice lead.*

FOOD AND FORAGING Like right whales, Bowhead Whales are skim feeders; however, their diet is much more varied. Their primary prey are copepods and krill, and they also eat a wide variety of other invertebrates. More than 60 prey species have been identified in the stomachs of Bowheads killed by the Inuit hunt in Alaska. Bowheads are usually solitary while foraging, although they occasionally echelon feed together.

STATUS AND CONSERVATION Like the right whales, the Bowhead was the target of intensive whaling in the pre-modern era. Whaling for Bowheads began in the North Atlantic in the 16th century, with thousands of animals killed in waters from Spitsbergen Island to Labrador. The Bering-Chukchi-Beaufort population was first hunted in the mid-19th century, and the Sea of Okhotsk population was exploited shortly thereafter. Of the five populations recognized today, all but one remain highly endangered. The exception is the Bering-Chukchi-Beaufort population, estimated at more than 8,000 animals and steadily increasing despite continued hunting by Inuit. The Spitsbergen population is believed to be close to extinction, while the populations in Hudson Bay–Foxe Basin and Davis Strait–Baffin Bay may number a few hundred animals. The size of the Okhotsk Sea population is unknown but is probably at most a few hundred due to exploitation by the Soviet Union that continued into the 1960s. With the exception of the strictly managed Inuit hunt in Alaska, Bowheads are protected throughout their range.

Killer Whale

Orcinus orca
(Linnaeus, 1758)

- TALL, ERECT DORSAL FIN, MORE PROMINENT IN ADULT MALE
- LARGE ROUNDED FLIPPERS
- DISTINCTIVE BLACK-AND-WHITE COLOR PATTERN
- LARGE SIZE RELATIVE TO OTHER DOLPHINS
- COSMOPOLITAN DISTRIBUTION

MALE

FEMALE

The Killer Whale's exposure on television, in movies, and at oceanariums has made the species an icon. As recently as the 1960s, Killer Whales, also known as Orcas, were feared and persecuted; however, after a few individuals were brought into captivity and trained, the public's view of them became transformed. Today these whales are much loved. Killer Whales are among the best-known cetaceans, thanks mainly to the work of researchers based on the west coast of North America, who for more than three decades have studied the pods off Washington, British Columbia, and Alaska. The world population of Killer Whales seems to consist of specialized subpopulations, each adapted to live off the resources available within its home range. In this sense, Killer Whales are much like wolves. Some scientists believe that differences in morphology, genetics, ecology, and behavior among different groups of Killer Whales are a sufficient basis for establishing different races, subspecies, and perhaps even species.

DESCRIPTION The Killer Whale's body is extremely robust; it is the largest delphinid. The head is conical and lacks a well-defined beak. The dorsal fin, situated at midback, is large, prominent, and highly variable in shape: falcate in females and juveniles, erect and almost spike-like in adult males. On males, the dorsal fin can reach a height of 3 to 6 feet (1–1.8 m). The flippers are large, broad, and rounded, very different from the typically sickle-shaped flippers of most delphinids. There are 10 to 14 pairs of large pointed teeth in both the upper and lower jaws.

The color pattern consists of highly contrasting areas of black and white. The white ventral zone, continuous from lower jaw to anus, narrows between the all-black flippers and branches behind the umbilicus. The ventral surface of the flukes and adjacent portion of the caudal peduncle are also white. The back and sides are black, except for white patches on the flanks that rise from the uro-genital region and prominent oval white patches slightly above and behind the eyes. There is a highly variable, gray to white saddle marking on the back behind the dorsal fin.

RANGE AND HABITAT Considered the most widespread cetacean, the Killer Whale is truly cosmopolitan and is not limited by such habitat features as water temperature, or depth. It occurs in highest densities at high latitudes, especially in areas with an abundance of prey. Its movements generally appear to track those of favored prey species or to take advantage of pulses in prey abundance or vulnerability, such as during times and in areas of fish spawning and seal pupping.

In the Antarctic during summer, most Killer Whales position themselves near the ice edge and in channels within the pack ice, where they prey on baleen whales, penguins, and seals. It is uncertain how far, or where, they migrate. Some may remain in antarctic waters year-round. In the Arctic, Killer Whales rarely move close along or into the pack ice. Researchers studying Killer Whales in Washington and British Columbia have identified "resident" and "transient" pods,

RANGE

KILLER WHALE
FAMILY DELPHINIDAE

MEASUREMENTS AT BIRTH		
LENGTH	7'3"–8'6" (2.2–2.6 m)	
WEIGHT	About 350 lb (160 kg)	
MAXIMUM MEASUREMENTS		
LENGTH	**MALE**	30' (9 m)
	FEMALE	26' (7.9 m)
WEIGHT	**MALE**	At least 12,000 lb (5,600 kg)
	FEMALE	At least 8,400 lb (3,800 kg)
LIFE SPAN		
MALE	50–60 years	
FEMALE	80–90 years	

Killer Whales evoke strong responses from people in part because they are at once large, intimidating, and playful. Here a young breaching animal displays the species' broad flippers and white ventral markings, while a larger animal in the foreground shows the impressive dorsal fin and the distinctive light "saddle" marking on the back immediately behind the fin.

although both types of pod are present year-round. Some individuals occupy very large ranges. For example, photo-identification studies have shown that some Killer Whales move between Alaska and California. (The range map for this species shows areas where Killer Whales are known to occur but probably under-represents the total range of the species.)

SIMILAR SPECIES The Killer Whale is among the easiest of the cetaceans to identify. However, at a distance, the relatively prominent dorsal fins of the False Killer Whale and Risso's Dolphin can cause confusion. Both species overlap with Killer Whales in tropical and temperate waters.

BEHAVIOR The basic social unit of resident Killer Whales in Washington and British Columbia is the matrilineal group, consisting of two to four generations of two to nine related individuals. Matrilineal groups are stable over long periods, and all members may contribute to calf rearing. A number of groups that spend much of their time together constitute a pod. The largest resident pod in the area of Washington and British Columbia contains close to 60 individuals. Resident pods greet one another by facing off in two tight lines, then mingling in a relaxed manner, as if to reaffirm their social bonds. While adult females tend to be associated with one or more pods, adult males are sometimes solitary.

Killer Whales often breach, spyhop, and slap the surface with their flukes or flippers. They exhibit varied responses to vessels, ranging from indifference to curiosity. Mass strandings occur occasionally, and pods sometimes become trapped in tidal ponds or inlets. Wind-blown or fast-forming ice can be a hazard for Killer Whales in the Arctic and Antarctic, forcing them to remain in small pools of open water for prolonged periods.

REPRODUCTION In the resident population off Washington and British Columbia, calving occurs year-round, with a peak between autumn and spring. The average calving interval is five years. Females usually stop reproducing after about 40 years of age. Studies of whales in captivity suggest that gestation lasts 15 to 18 months. Although Killer Whales begin eating solid food at a very young age, they continue to nurse for at least a year and may not be fully weaned until close to two years of age.

RIGHT: These spyhopping Killer Whales belong to one of the populations that visit or reside in inshore waters of Washington state and British Columbia.
BELOW: This group of Killer Whales includes three adult males, each of them readily identifiable by the tall, triangular dorsal fin. The animals in the center of the group are either females or juvenile males.

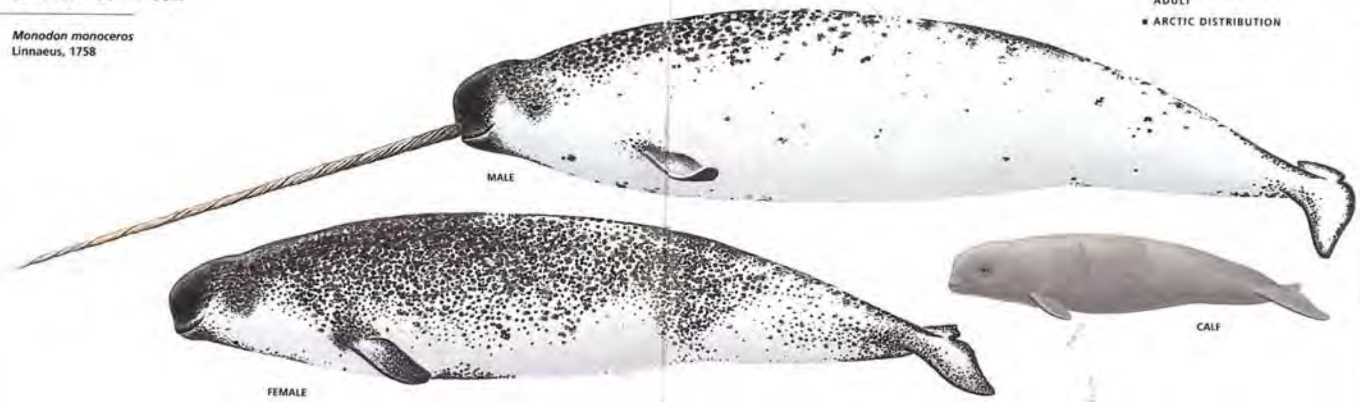
FOOD AND FORAGING Killer Whales eat a diet ranging from small schooling fish and squid to large baleen and sperm whales. Their prey items include sea turtles, otters, sirenians, sharks, rays, and even deer or moose, which they catch swimming across channels. Pods tend to specialize. For example, some depend largely on salmon, tuna, or herring, while others patrol pinniped haulouts or follow migratory whale populations, much as wolves follow caribou herds. Killer Whales obviously need to use cooperative hunting to harass and subdue large prey items, but they also cooperate to consolidate and maintain tight balls of baitfish, taking turns slicing through the schools to feed. Killer Whales also steal fish from longlines, scavenge on discarded fishery bycatch, and selectively eat the tongues of baleen whales. Prey may be strongly influenced by their fear of Killer Whales; pinnipeds flee from the water onto land or ice and whales and dolphins move into nearshore shallows or hide in cracks in pack ice.

STATUS AND CONSERVATION While as a species the Killer Whale is not endangered, whaling or live-capture operations have depleted some regional populations. Resident and transient populations off Washington and British Columbia number only in the low hundreds, and are threatened by pollution, heavy ship traffic, and possibly reduced prey abundance. There is concern that intensive whale-watching operations may influence the behavior of Killer Whales, and that the loud "seal-scarers" used to protect salmon pens from predation by pinnipeds may be driving Killer Whales away from their preferred inshore resting and foraging waters. About 8,500 Killer Whales are thought to occur in the eastern tropical Pacific, at least 850 in Alaskan waters, possibly close to 2,000 off Japan, and about 80,000 in the Antarctic during summer. Estimates from most other areas are in the hundreds or low thousands. Whalers in Japan, Indonesia, Greenland, and the West Indies continue to hunt Killer Whales; while the whales are killed in only small numbers, the effects of hunting on local populations could be substantial.

Narwhal

Monodon monoceros
Linnaeus, 1758

- LONG TUSK ON ADULT MALES
- SMALL ROUNDED HEAD WITH NO BEAK
- NO DORSAL FIN
- SPOTTED, BLACK-AND-WHITE DORSAL COLORATION IN ADULT
- ARCTIC DISTRIBUTION

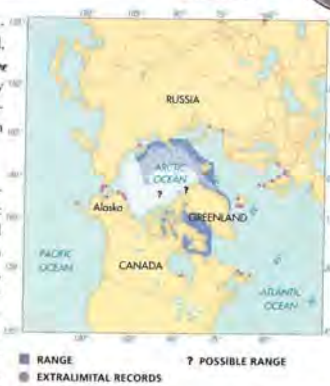


In the popular imagination, the Narwhal is inextricably linked with the fabled unicorn, and for good reason: The adult male's long, spiraled tusk came closer than anything else in nature to "proving" the unicorn's existence. In fact, from the Middle Ages onward, traders and chemists conspired to keep the existence of the Narwhal a secret, while selling its tusks as "unicorn horns" for immense profit. Although it is no longer linked to the mythical horned horse, the Narwhal is still a compelling creature because of the remoteness and harshness of its arctic environment as well as its unusual appearance. Thanks to the efforts of native local people and adventurous scientists equipped with powerful new high-tech tools, we are finally beginning to learn some of the details about the lives of Narwhals, even during the dark polar winter.

DESCRIPTION The Narwhal has a short rounded head with no beak. The melon is bluff, protruding somewhat forward of the small upturned mouth. The small flippers are broad but short. The flukes of adults are strongly convex on the rear margin; from an aerial perspective, they are reminiscent of butterfly wings. Like Belugas, Narwhals have no dorsal fin but rather a low fleshy ridge along the posterior half of the back. All Narwhals lack functional teeth inside the mouth, and most females remain essentially toothless throughout life. In males (and rarely females), the left of two upper-jaw teeth erupts through the lip at two or three years of age and keeps growing. The erupted portion of this tusk can be up to 9 feet (2.7 m) long, and the entire tusk can weigh more than 22 pounds (10 kg). In most cases, the surface of the tusk has a leftward spiral, but the axis is straight. Occasionally even the axis itself is twisted. The right tooth sometimes also erupts so that the animal is "double-tusked."

Adult Narwhals are spotted black and white on the back and upper sides. Old individuals can be almost completely white, with black areas limited to the center of the back, the top of the head, and the edges of the appendages. Newborn Narwhals are light gray but become almost black by the time they are weaned. Thereafter, they become mottled as white areas begin to appear on the belly and sides.

RANGE AND HABITAT Narwhals have a discontinuous arctic distribution. They are most abundant in deep waters that branch northward from the North Atlantic basin, especially Hudson Strait, northwestern Hudson Bay, Foxe Basin, Davis Strait, Baffin Bay, and Lancaster Sound. Another center of distribution is in the Greenland Sea, with small groups also occurring in parts of the northern Barents Sea. Their migrations are tuned to the formation and movement



NARWHAL
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH
LENGTH 5'3" (1.6 m)
WEIGHT 176 lb (80 kg)

MAXIMUM MEASUREMENTS
LENGTH **MALE** 15'6" (4.7 m)
FEMALE 14' (4.2 m)
WEIGHT **MALE** 3,500 lb (1,600 kg)
FEMALE 2,200 lb (1,000 kg)

LIFE SPAN
At least 25 years, possibly 50

Narwhals occasionally lift their flukes as they dive. The ornately curved flukes are distinctive in both color and shape.

of sea ice. As the ice disintegrates and breaks up in spring, Narwhals follow the receding edge of the pack ice and use small cracks and melt holes to penetrate deep sounds and fjords as quickly as possible. They reside in these areas throughout the summer and early fall. As the ice cover re-forms, they head for offshore wintering areas where the ice is constantly in motion, allowing them to find breathing space between the floes.

SIMILAR SPECIES The Beluga is the only species that might be confused with the Narwhal, primarily with females and juveniles since the tusk of adult male Narwhals is so distinctive. Belugas are either solid gray or white, never black, mottled, or spotted. Both species are fairly gregarious, and usually at least a few individuals within a group have readily identifiable features. Belugas can occur in all areas inhabited by Narwhals, and occasionally the two species are seen together. However, they normally do not form mixed groups or schools; both species tend to form large single-species concentrations, particularly in summer.

BEHAVIOR Narwhals often form large aggregations of several hundred animals during summer. Such aggregations, however, consist of smaller, fairly close-knit groups of a few up to about 20 individuals. These groups are typically homogeneous, consisting of animals of the same sex or a single age class. In winter while distributed in the pack ice, Narwhals seem to be more scattered and solitary, perhaps owing to the patchiness of cracks and holes in the ice. The presence of scars and wounds in the head region, and the high incidence of broken tusks, suggest that adult males fight one another. Such fighting could play a role in establishing dominance and thus access to mating opportunities. While Narwhals have been seen apparently crossing tusks above the surface, there is no concrete evidence that they fence with them. Polar Bears are known to kill Narwhals that are trapped in small pools of open water, and Killer Whales prey on them in their inshore summering areas. Although they do not mass strand like pilot whales, Narwhals are subject to catastrophic mortality from entrapment by wind-driven or fast-forming ice. The frequency and scale of such mortality are especially high in the Disko Bay region of West Greenland.

REPRODUCTION Narwhals mate during late winter and spring (peaking in April), when the animals are generally inaccessible for observation. Gestation lasts about 15 months, and most calves are born in summer (July–August, peaking around the first of August) when the animals are in fjords. Lactation and nursing lasts for at least a year, so the calving interval is at least two years and probably averages three.

FOOD AND FORAGING Narwhals are deep divers. They forage in the entire water column, taking pelagic fish (especially arctic cod), squid, and shrimp, as well as bottom-dwelling species such as Greenland halibut. Dives can last as long as 20 minutes and reach depths of more than 3,300 feet (1,000 m). Narwhals apparently suck prey into their mouth and swallow it whole. They do not use the tusk to spear fish.

STATUS AND CONSERVATION Narwhals have long been hunted by native peoples for food, oil, and ivory. The skin (called "maktaq," variously spelled) is considered a delicacy. Commercial whalers hunted Narwhals but generally only on a casual basis, as Bowhead Whales were their preferred quarry in the Arctic. For a brief period in the early 20th century, the Hudson's Bay Company purchased Narwhal skins and tusks for export (the former to be used to make soft leather gloves). Tusks continue to be profitable export items, and maktaq has high commercial value in northern towns in both Canada and Greenland. Population estimates based on aerial surveys are about 35,000 Narwhals in Baffin Bay, 1,400 in Hudson Strait, and 300 in Scoresby Sound (East Greenland). These numbers were not corrected to account for submerged animals, and the true range-wide abundance may be greater than 50,000. The principal known threat to Narwhal populations is hunting, particularly since it is now facilitated by fast motorized boats and high-powered rifles.

As they migrate toward their summering areas in deep arctic fjords, Narwhals take advantage of cracks and leads in the pack ice, crowding one another for breathing space. The two individuals in the foreground appear to be young males, their tusks projecting forward for only a foot or two, and their dark bodies only beginning to whiten.

This aerial view of four Narwhals, taken in the eastern Canadian Arctic, shows many of the species' distinctive features, including the long spiraled tusk, the small rounded head, the mottled, black-and-white coloration, and the absence of a dorsal fin. The low dorsal ridge appears as a dark line along the middle of the back of the older whiter animals.

LEFT: *Largha Seals, also called Spotted Seals, are similar in body shape, size, and coloration to Harbor Seals, but Largha Seals haul out and breed principally on pack ice, compared to the terrestrial habitats preferred by Harbor Seals.* **RIGHT:** *Newborn Largha Seals also have a thick white lanugo pelage, which is shed when they are about three to four months old, revealing the adult spotted color pattern.*

in the open ocean, their behavior is virtually unstudied. They may occur in well-spaced family groups on the sea ice during the breeding season in spring.

REPRODUCTION Largha Seals are thought to be seasonally monogamous. During the breeding season, they are most often seen well spaced out on the ice in triads consisting of an adult female, her pup, and an adult male. Females give birth on the surface of ice floes from January through mid-April, with a peak in mid- to late March. Males are thought to join a female and her pup about a week after pupping, and the group remains together until the pup is weaned at three to four weeks old, at which time mating occurs and the male leaves the group. This system limits the mating opportunities of males during a breeding season; however, males that mate early in the season may later find an unattended female-pup pair or may displace another male from a triad. Mating evidently takes place in the water.

FOOD AND FORAGING Adults and juveniles eat a variety of schooling fish (pollock, capelin, arctic cod, and herring), epibenthic fish (especially flounder, halibut, and sculpin), and crabs and octopus at depths of up to 1,000 feet (300 m). Weaned pups apparently mostly eat amphipods, krill, and other small crustaceans.

STATUS AND CONSERVATION Native peoples along the eastern Russian coast and in Alaska have traditionally killed small numbers of Largha Seals for subsistence. The Soviet Union made some commercial harvests from the 1930s through the 1980s in the Sea of Okhotsk and the western Bering Sea, and Japan also commercially hunted these seals in the Sea of Okhotsk at times. Largha Seals occasionally drown in fishing nets set in coastal waters of northern Hokkaido, Japan. Population abundance is poorly known but has been estimated at around 350,000 to 400,000, with about half of the seals living in the Bering and Chukchi Seas.

Ringed Seal

Pusa hispida
(Schreber, 1775)

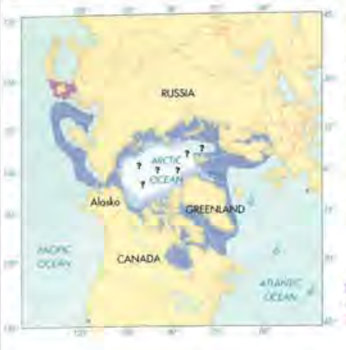
- DARK DORSAL PELAGE WITH SCATTERED, IRREGULAR LIGHT RINGS AND DARK BACKGROUND
- SMALLEST TRUE SEAL NEXT TO BAIKAL SEAL
- EXCAVATES BIRTH LAIRS BENEATH ICE SURFACE
- DISTRIBUTION CLOSELY ASSOCIATED WITH LANDFAST AND PACK ICE
- WIDELY DISPERSED IN ARCTIC BASIN AND BERING, OKHOTSK, JAPAN, AND BALTIC SEAS

The smallest and most common seals in the Arctic Ocean and the Bering and Baltic Seas, Ringed Seals have long been important prey for native inhabitants of the Arctic. They are also the top prey of Polar Bears, and during the breeding season, Ringed Seals excavate birth lairs in ice and snow to protect themselves against this predation. The Baikal Seal is the only other pinniped known to use such structures for giving birth and raising pups. Scientists recognize five subspecies of the Ringed Seal, including two freshwater populations. The Ringed Seal was formerly included in the genus *Phoca* along with the Baikal and Caspian Seals. However, taxonomists have recently reinstated these three species to the genus *Pusa*, which is derived from the common name for the Ringed Seal used by the Inuit of Greenland and various eastern North Atlantic cultures. The specific name is derived from the Latin word *hispidus*, meaning "hairy" or "bristly," and refers to the adult pelage, which is often stiffer than that of other phocid pinnipeds. The common name refers to the scattered irregular rings on the pelage.

DESCRIPTION The Ringed Seal has a small plump body and a small head. The snout is narrow, short, and cat-like. The flippers are small, with short slender claws on the hindflippers and robust claws on the foreflippers that may be more than an inch long. There are nine pairs of teeth in the upper jaw and eight pairs in the lower jaw.

The pelage of adults is dark dorsally with scattered irregular rings, and lighter and less ringed ventrally. Newborn pups have a woolly, white lanugo coat that they shed at about six to eight weeks old to reveal an unspotted pelage that is uniformly dark silver or gray dorsally and light silver ventrally. The ringed pattern develops at the first annual molt when seals are a little more than one year old.

RANGE AND HABITAT Ringed Seals have a circumpolar distribution throughout the Arctic Ocean, Hudson Bay, and Baltic and Bering Seas. They are closely associated with sea ice. In summer they often occur along the receding ice edge and farther north in denser pack ice. Five subspecies are recognized. The most widely dispersed form, *Pusa hispida hispida*, occurs in the Arctic Basin. *P. h. ochotensis* occurs in the Sea of Okhotsk and the Sea of Japan, and *P. h. botnica* occurs in the Baltic Sea. Freshwater populations



RINGED SEAL

FAMILY PHOCIDAE

MEASUREMENTS AT BIRTH
LENGTH 26" (60–65 cm)
WEIGHT 9–11 lb (4–5 kg)

MAXIMUM MEASUREMENTS
LENGTH 5'3" (1.6 m)
WEIGHT 240 lb (110 kg)

LIFE SPAN
25–30 years

RANGE
? POSSIBLE RANGE
VAGRANTS

include *P. h. saimensis* in Lake Saimaa in eastern Finland and *P. h. lagodensis* in Lake Ladoga, Russia. Vagrants from the marine populations have ranged as far south as Portugal in the Atlantic Ocean and California in the Pacific.

SIMILAR SPECIES Harbor, Harp, Hooded, Gray, Bearded, Ribbon, and Largha Seals may occupy similar habitats in various parts of the Ringed Seal's range. All but Harbor and Largha Seals can be readily distinguished by their body and head morphology and pelage patterns. Largha Seals, which may overlap in the Bering, Okhotsk, and Japan Seas, have a spotted rather than a ringed pelage pattern and are larger but more slender than Ringed Seals, with relatively longer, wider snouts. Harbor Seals prefer ice-free habitats and are rarely seen in ice.

BEHAVIOR Though there are areas of high density of Ringed Seals through the Arctic, these seals do not aggregate in large groups. Rather, they are largely solitary and space out from one another by hundreds of yards or more. During the breeding season, triads of an adult female, her pup, and an adult male form short-term family groups. These groups are not easily observed, however, as the seals remain in lairs in the ice and snow excavated by the females for pupping and nursing. The excavation of lairs in and under sea and lake ice is unique to Ringed Seals and is evidently an adaptation for escaping predation by Polar Bears. Some lairs are quite complex, with several chambers. Females evidently leave pups in the lairs for short periods while they forage nearby. Throughout winter, Ringed Seals maintain breathing holes by chewing away newly formed ice. Individuals may favor particular breathing holes, perhaps excluding other seals from loosely associated underwater territories. Ringed Seals molt in June and July; while molting, they spend more time basking on the surface of the ice than in other seasons. Ringed Seals are the primary prey of Polar Bears, and are also occasionally eaten by Walruses and Killer Whales.

REPRODUCTION The breeding system of the Ringed Seal is thought to be either mildly polygynous or serially monogamous, but is not well known because of the difficulty in finding and observing seals during the breeding season. Females excavate lairs in the pressure ridges or accumulated snow on sea or lake ice, and in Lake Saimaa in snowdrifts along the shoreline. They give birth in March and April in most areas, a little earlier in the Baltic Sea. Pups are weaned and mating occurs between April and May. Males evidently patrol under the ice searching for receptive females. They may stay with a female for several days until they mate, and then return to the water to patrol for another potential mate.

FOOD AND FORAGING When feeding along the sea-ice edge in summer, Ringed Seals eat mostly polar cod, even though the potential prey biomass there is dominated by pelagic crustaceans. The seals evidently selectively choose these prey, which represent about only 1 percent of the fish and crustacean biomass. In these areas, Ringed Seals eat smaller cod, evidently at shallower depths than the sympatric Harp Seals. Most dive depths for *P. h. hispida* are 35 to 150 feet (10–45 m) for sexually mature males, and 330 to 475 feet (100–145 m) for subadult males and postpartum females. Most dives last about 4 minutes for adult males and 7½ minutes for adult females. The longest dive recorded is about 23 minutes, although the seal may actually have been resting on the sea bottom rather than feeding.

STATUS AND CONSERVATION Ringed Seals have been key subsistence prey for native arctic peoples, who hunt them for food for humans and dogs as well as for skins to make clothing. Levels of PCBs are higher in seals taken by subsistence hunters in the European and Russian Arctic than in other arctic regions. These higher levels are thought to be due to continued use of PCBs in Russian electrical equipment. Though never completely surveyed, the species may number as many as 4 million. Ringed Seals in the Baltic Sea are considered to be at risk because of heavy pollution, which affects the seals' immune systems and reproductive success. Although about half of the Ringed Seals in Lake Saimaa breed in coastal areas located within national parks, poaching and threats associated with fisheries in other parts of the lake seriously threaten this small population.

OPPOSITE: *Ringed Seals have a robust body and small head and foreflippers. The dark pelage background with scattered light rings is characteristic of the species.* **RIGHT:** *Ringed Seals are the primary prey of Polar Bears and so are extremely wary when surfacing in their breathing holes, which may be staked out by patient, hungry bears. Ringed Seals maintain these breathing holes by abrading the ice with their canine teeth.*

GOLDER

APPENDIX B

Vessel Track Information

Medium (>50 m) and large (>100 m) vessel traffic in SSA during 2019 BH Field Program

**Black Text = vessels observed. Grey text = Vessels not observed

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
1	August 6, 2019	(01:36 - 02:42)	Despina V	Bulk (ore) carrier	North	under 9.0
2	August 6, 2019	(04:34 - 05:53)	MV Golden Brilliant	Bulk (ore) carrier	South	under 9.0
3	August 7, 2019	(00:30 - 01:34)	Golden Suek	Bulk (ore) carrier	North	under 9.0
4	August 7, 2019	(03:57 - 04:59)	Pabur	Bulk (ore) carrier	South	under 9.0
5	August 7, 2019	(20:19 - 21:24)	MV Golden Brilliant	Bulk (ore) carrier	North	under 9.0
6	August 7, 2019	(22:45 - 23:57)	Flag Mette	Bulk (ore) carrier	South	under 9.0
7	August 8, 2019	(18:12 - 19:22)	Golden Pearl	Bulk (ore) carrier	North	under 9.0
8	August 8, 2019	(20:44 - 21:50)	Patricia V	Bulk (ore) carrier	South	under 9.0
9	August 9, 2019	(13:33 - 14:43)	Horizon Star	General Cargo	North	under 9.0
10	August 9, 2019	(16:10 - 17:14)	Pabur	Bulk (ore) carrier	North	up to 9.1
11	August 9, 2019	(18:56 - 20:05)	Golden Saguenay	Bulk (ore) carrier	South	under 9.0
12	August 10, 2019	(12:29 - 15:28)	CDN War Ship	Army	South	up to 17.2
13	August 10, 2019	(13:55 - 15:22)	Flag Mette	Bulk (ore) carrier	North	under 9.0
14	August 10, 2019	(15:28 - 15:56)	CDN War Ship	Army	North	up to 17.1
15	August 10, 2019	(16:18 - 17:36)	Georg Oldendorff	Bulk (ore) carrier	South	up to 9.1
16	August 11, 2019	(08:48 - 10:00)	Patricia V	Bulk (ore) carrier	North	under 9.0
17	August 11, 2019	(11:43 - 12:58)	Golden Opal	Bulk (ore) carrier	South	up to 9.0

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
18	August 12, 2019	(06:40 - 07:50)	Golden Saguenay	Bulk (ore) carrier	North	under 9.0
19	August 12, 2019	(09:35 - 10:49)	Golden Diamond	Bulk (ore) carrier	South	under 9.0
20	August 13, 2019	(02:50 - 03:58)	Georg Oldendorff	Bulk (ore) carrier	North	up to 9.0
21	August 13, 2019	(06:07 - 07:22)	Golden Opportunity	Bulk (ore) carrier	South	under 9.0
22	August 13, 2019	(10:55 - 11:59)	Biglift Barentsz	General Cargo	South	up to 9.0
23	August 13, 2019	(20:47 - 21:54)	Golden Opal	Bulk (ore) carrier	North	under 9.0
24	August 13, 2019	(23:39 - 00:49)	Nordic Odin	Bulk (ore) carrier	South	under 9.0
25	August 14, 2019	(18:46 - 20:02)	Golden Diamond	Bulk (ore) carrier	North	under 9.0
26	August 14, 2019	(22:01 - 23:11)	Golden Ice	Bulk (ore) carrier	South	under 9.0
27	August 14, 2019	(22:25 - 23:34)	NS Energy	Bulk (ore) carrier	South	under 9.0
28	August 15, 2019	(20:37 - 21:52)	Bulk Endurance	Bulk (ore) carrier	South	up to 9.2
29	August 15, 2019	(17:30 - 18:45)	Golden Opportunity	Bulk (ore) carrier	North	under 9.0
30	August 16, 2019	(18:17 - 19:28)	Golden Ice	Bulk (ore) carrier	North	under 9.0
31	August 17, 2019	(05:36 - 06:50)	Gisela Oldendorf	Bulk (ore) carrier	South	under 9.0
32	August 17, 2019	(06:48 - 07:54)	Miena Desgagnes	General Cargo	South	under 9.0
33	August 17, 2019	(07:15 - 08:29)	Sarah Desgagnes	Oil And Chemical Tanker	South	under 9.0
34	August 17, 2019	(16:18 - 17:31)	Nordic Odin	Bulk (ore) carrier	North	under 9.0

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
35	August 17, 2019	(21:46 - 23:06)	Nordika Desgagnes	General Cargo	South	under 9.0
36	August 18, 2019	(04:33 - 05:40)	Kumpula	Bulk (ore) carrier	South	under 9.0
37	August 18, 2019	(16:43 - 17:48)	Gisela Oldendorf	Bulk (ore) carrier	North	up to 9.1
38	August 19, 2019	(15:45 - 16:53)	Kumpula	Bulk (ore) carrier	North	under 9.0
39	August 19, 2019	(18:39 - 19:48)	Nordic Oasis	Bulk (ore) carrier	South	under 9.0
40	August 20, 2019	(20:57 - 22:28)	NS Energy	Bulk (ore) carrier	North	under 9.0
41	August 20, 2019	(23:14 - 00:30)	Golden Enterprise	Bulk (ore) carrier	South	under 9.0
42	August 21, 2019	(17:52 - 18:58)	Bulk Endurance	Bulk (ore) carrier	North	under 9.0
43	August 21, 2019	(20:41 - 21:57)	NS Yakutia	Bulk (ore) carrier	South	under 9.0
44	August 22, 2019	(08:34 - 09:46)	Sarah Desgagnes	Oil And Chemical Tanker	North	under 9.0
45	August 22, 2019	(15:25 - 16:44)	Nordic Oasis	Bulk (ore) carrier	North	under 9.0
46	August 22, 2019	(18:18 - 19:42)	Golden Bull	Bulk (ore) carrier	South	under 9.0
47	August 23, 2019	(08:48 - 09:54)	Miena Desgagnes	General Cargo	North	up to 9.5
48	August 23, 2019	(12:54 - 14:07)	Golden Bull	Bulk (ore) carrier	North	up to 9.3
49	August 23, 2019	(12:36 - 13:46)	NS Yakutia	Bulk (ore) carrier	North	up to 9.8
55	August 24, 2019	(05:23 - 06:57)	NS Yakutia	Bulk (ore) carrier	South	up to 9.4

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
53	August 24, 2019	(08:02 - 09:24)	Golden Enterprise	Bulk (ore) carrier	North	under 9.0
52	August 24, 2019	(11:12 - 12:36)	Golden Bull	Bulk (ore) carrier	South	under 9.0
54	August 24, 2019	(18:50 - 20:17)	Sagar Samrat	Bulk (ore) carrier	South	under 9.0
51	August 24, 2019	(19:47 - 21:32)	Nordika Desgagnes	General Cargo	North	under 9.0
57	August 25, 2019	(08:58 - 10:09)	NS Yakutia	Bulk (ore) carrier	North	up to 9.2
56	August 25, 2019	(12:25 - 13:33)	AM Buchanan	Bulk (ore) carrier	South	under 9.0
58	August 26, 2019	(07:35 - 09:04)	Golden Bull	Bulk (ore) carrier	North	under 9.0
59	August 26, 2019	(10:40 - 11:54)	Sea Neptune	Bulk (ore) carrier	South	under 9.0
60	August 27, 2019	(14:30 - 15:36)	Happy Diamond	General Cargo	South	up to 9.1
61	August 27, 2019	(10:00 - 11:08)	Nordic Oshima	Bulk (ore) carrier	South	under 9.0
62	August 27, 2019	(07:02 - 08:08)	Sagar Samrat	Bulk (ore) carrier	North	under 9.0
64	August 28, 2019	(05:04 - 06:15)	AM Buchanan	Bulk (ore) carrier	North	up to 9.0
63	August 28, 2019	(07:49 - 08:59)	Nordic Odyssey	Bulk (ore) carrier	South	under 9.0
65	August 29, 2019	(08:56 - 10:04)	Nordic Olympic	Bulk (ore) carrier	South	under 9.0
66	August 29, 2019	(05:59 - 07:16)	Sea Neptune	Bulk (ore) carrier	North	under 9.0
69	August 30, 2019	(04:31 - 05:46)	Nordic Oshima	Bulk (ore) carrier	North	under 9.0
67	August 30, 2019	(05:52 - 07:04)	Gebe Oldendorff	Bulk (ore) carrier	South	up to 9.1

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
68	August 30, 2019	(18:24 - 19:35)	Claude A. Desgagnes	General Cargo	South	up to 9.1
70	August 31, 2019	(01:51 - 03:00)	Nordic Odyssey	Bulk (ore) carrier	North	under 9.0
71	August 31, 2019	(05:23 - 06:40)	Golden Ruby	Bulk (ore) carrier	South	under 9.0
72	August 31, 2019	(23:22 - 00:31)	Gebe Oldendorff	Bulk (ore) carrier	North	under 9.0
73	September 1, 2019	(03:06 - 04:21)	Pabal	Bulk (ore) carrier	South	under 9.0
74	September 1, 2019	(15:03 - 16:10)	Sarah Desgagnes	Oil And Chemical Tanker	South	up to 9.0
75	September 1, 2019	(20:10 - 21:18)	Nordic Olympic	Bulk (ore) carrier	North	under 9.0
76	September 1, 2019	(22:19 - 23:27)	Nordic Orion	Bulk (ore) carrier	South	under 9.0

APPENDIX C

Test Statistics and Coefficient Estimates

RAD analysis

Table C-1: Test statistics of mixed generalized linear model of narwhal counts (type II *P* values)

Parameter	Chi squared	Df	*P* value
Negative binomial component of model			
Day	19.118	2	**<0.001**
Year	5.536	4	0.237
Stratum	412.087	9	**<0.001**
Substratum	260.336	2	**<0.001**
Glare	65.221	2	**<0.001**
Beaufort scale	316.196	5	**<0.001**
Tide	41.704	3	**<0.001**
Distance	15.617	3	**0.001**
Vessel direction relative to BSA	0.953	1	0.329
North- or southbound vessel	5.731	1	**0.017**
Vessel presence within 10 km from substratum	8.939	2	**0.011**
Time since last shooting event	150.040	3	**<0.001**
Hunting event within 3 h prior to observation	21.831	1	**<0.001**
Presence of small vessels within the SSA	0.884	1	0.347
Distance:Vessel direction relative to substratum	3.394	3	0.335
Distance:North- or southbound vessel	11.368	3	**0.010**
Vessel direction relative to substratum:North- or southbound vessel	13.041	1	**<0.001**
Distance:Vessel direction relative to substratum:North- or southbound vessel	9.480	3	**0.024**
Zero-inflation component of model			
Stratum	49.705	9	**<0.001**
Substratum	44.040	2	**<0.001**
Year	216.960	4	**<0.001**

Table C-2: Coefficient estimates for fixed effects in a mixed generalized linear model of narwhal counts (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare=”N”, Beaufort = 0, Stratum = “A”, Substratum = “1”, no vessels within 10 km from substratum, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA)	-1.955	0.405	-4.821	<0.001
Day of year[1]	73.070	25.316	2.886	0.004
Day of year squared[1]	-89.150	25.591	-3.484	<0.001
Year (2015)	0.460	0.482	0.954	0.34
Year (2016)	0.961	0.493	1.951	0.051

Parameter	Coefficient	SE	*z* value	*P* value
Year (2017)	0.949	0.496	1.914	0.056
Year (2019)	0.879	0.495	1.775	0.076
Stratum (B)	-0.011	0.163	-0.065	0.948
Stratum (C)	0.330	0.169	1.956	0.051
Stratum (D)	1.032	0.166	6.217	<0.001
Stratum (E)	1.073	0.163	6.588	<0.001
Stratum (F)	1.494	0.161	9.266	<0.001
Stratum (G)	2.027	0.161	12.569	<0.001
Stratum (H)	2.173	0.163	13.307	<0.001
Stratum (I)	2.359	0.165	14.305	<0.001
Stratum (J)	2.665	0.210	12.689	<0.001
Substratum (2)	0.535	0.056	9.644	<0.001
Substratum (3)	-0.239	0.080	-2.970	0.003
Glare (L)	0.172	0.034	5.110	<0.001
Glare (S)	-0.426	0.078	-5.425	<0.001
Beaufort (1)	0.060	0.067	0.894	0.371
Beaufort (2)	-0.320	0.071	-4.499	<0.001
Beaufort (3)	-0.857	0.087	-9.878	<0.001
Beaufort (4)	-1.028	0.107	-9.629	<0.001
Beaufort (5)	-1.429	0.157	-9.123	<0.001
Tide (Flood)	-0.235	0.043	-5.476	<0.001
Tide (High slack)	-0.286	0.051	-5.633	<0.001
Tide (Ebb)	-0.146	0.043	-3.427	0.001
Distance from vessel[1]	11.137	4.323	2.576	0.01
Distance from vessel squared[1]	-12.032	5.992	-2.008	0.045
Distance from vessel cubed[1]	-5.771	4.105	-1.406	0.16
Vessel heading away from substratum	-0.247	0.121	-2.033	0.042
Vessel southbound	-0.653	0.157	-4.173	<0.001
One vessel within 10 km from BSA	0.233	0.094	2.489	0.013
2+ vessels within 10 km from BSA	0.475	0.193	2.457	0.014
Time since shots fired[1]	-28.771	2.748	-10.469	<0.001
Time since shots fired squared[1]	7.774	3.732	2.083	0.037
Time since shots fired cubed[1]	-10.402	2.797	-3.719	<0.001
Hunting occurred within preceding 3 h	-0.265	0.057	-4.672	<0.001
Small vessels present within SSA	-0.031	0.033	-0.940	0.347
Vessel distance[1] : Vessel heading away from substratum	0.586	6.279	0.093	0.926
Vessel distance squared[1] : Vessel heading away from substratum	0.615	8.622	0.071	0.943

Parameter	Coefficient	SE	*z* value	*P* value
Vessel distance cubed[1] : Vessel heading away from substratum	1.940	6.062	0.320	0.749
Vessel distance[1] : Vessel southbound	-23.754	7.633	-3.112	0.002
Vessel distance squared[1] : Vessel southbound	13.093	10.681	1.226	0.22
Vessel distance cubed[1] : Vessel southbound	15.783	8.102	1.948	0.051
Vessel heading away from BSA : Vessel southbound	0.713	0.211	3.372	0.001
Vessel distance[1] : Vessel heading away from substratum : Vessel southbound	12.622	10.814	1.167	0.243
Vessel distance squared[1] : Vessel heading away from substratum : Vessel southbound	-14.516	14.918	-0.973	0.331
Vessel distance cubed[1] : Vessel heading away from substratum : Vessel southbound	-26.933	10.740	-2.508	0.012

[1] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Composition and Behaviour Analysis

Group Size

Table C-3: Test statistics of mixed generalized linear model of group size (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	14.505	4	**0.006**
Tide	1.149	3	0.765
Glare	16.737	2	**<0.001**
Beaufort scale	2.861	4	0.581
Distance	0.571	1	0.450
Vessel direction relative to BSA	0.0002	1	0.989
North- or southbound vessel	0.122	1	0.727
Vessel presence within 10 km from BSA	1.262	2	0.532
Time since last shooting event	11.352	1	**0.001**
Hunting event within 3 h prior to observation	25.888	1	**<0.001**
Presence of small vessels within the SSA	$1.5 * 10^{-5}$	1	0.997
Distance:Vessel direction relative to BSA	1.249	1	0.264
Distance:North- or southbound vessel	0.592	1	0.442
Vessel direction relative to BSA:North- or southbound vessel	1.659	1	0.198
Distance:Vessel direction relative to BSA:North- or southbound vessel	0.299	1	0.585

Table C-4: Coefficient estimates for fixed effects in a mixed generalized linear model of group size (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA)	0.885	0.192	4.614	<0.001
Year (2015)	0.259	0.206	1.261	0.207
Year (2016)	-0.310	0.189	-1.638	0.102
Year (2017)	-0.062	0.185	-0.335	0.737
Year (2019)	-0.250	0.186	-1.343	0.179
Glare (L)	-0.074	0.055	-1.342	0.180
Glare (S)	0.311	0.087	3.555	<0.001
Beaufort (1)	0.097	0.084	1.147	0.252
Beaufort (2)	0.052	0.097	0.542	0.588
Beaufort (3)	0.121	0.114	1.068	0.286
Beaufort (4 or higher)	0.004	0.151	0.024	0.981
Distance[1]	0.073	0.095	0.762	0.446
Vessel heading away from BSA	0.110	0.127	0.864	0.387
Vessel southbound	0.155	0.143	1.088	0.277
One vessel within 10 km from BSA	0.004	0.103	0.038	0.970
2+ vessels within 10 km from BSA	0.279	0.256	1.092	0.275
Tide (Flood)	-0.026	0.066	-0.385	0.700
Tide (High slack)	-0.040	0.076	-0.521	0.602
Tide (Ebb)	0.017	0.066	0.259	0.796
Time since shots fired[1]	-0.108	0.032	-3.370	0.001
Hunting occurred within preceding 3 h	0.242	0.048	5.088	<0.001
Small vessels present within SSA	0.000	0.048	-0.004	0.997
Vessel distance[1] : Vessel heading away from BSA	-0.145	0.125	-1.162	0.245
Vessel distance[1] : Vessel southbound	0.023	0.124	0.184	0.854
Vessel heading away from BSA : Vessel southbound	-0.231	0.183	-1.259	0.208
Vessel distance[1] : Vessel heading away from BSA : Vessel southbound	0.094	0.172	0.547	0.585

[1] = Variable was standardized prior to modeling.

Group Composition

Table C-5: Test statistics of mixed generalized linear model of group composition (presence of tusks; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	18.066	4	**0.001**
Group size	242.323	1	**<0.001**
Tide	0.039	3	0.998
Glare	4.370	2	0.113
Beaufort scale	7.602	4	0.107
Distance	1.552	3	0.670
Vessel direction relative to BSA	6.781	1	**0.009**
North- or southbound vessel	0.006	1	0.939
Vessel presence within 10 km from BSA	3.299	2	0.192
Time since last shooting event	5.033	3	0.169
Hunting event within 3 h prior to observation	4.110	1	**0.043**
Presence of small vessels within the SSA	2.082	1	0.149
Distance:Vessel direction relative to BSA	4.133	3	0.247
Distance:North- or southbound vessel	2.820	3	0.420
Vessel direction relative to BSA:North- or southbound vessel	2.431	1	0.119
Distance:Vessel direction relative to BSA:North- or southbound vessel	0.363	3	0.948

Table C-6: Coefficient estimates for fixed effects in a mixed generalized linear model of group composition (presence of tusks; type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA, average group size)	-0.983	0.551	-1.785	0.074
Year (2015)	0.188	0.493	0.382	0.702
Year (2016)	-0.579	0.442	-1.308	0.191
Year (2017)	-0.820	0.437	-1.876	0.061
Year (2019)	-1.220	0.440	-2.775	0.006
Group size[1]	0.761	0.049	15.567	<0.001
Glare (L)	-0.276	0.219	-1.257	0.209
Glare (S)	-0.661	0.360	-1.836	0.066
Beaufort (1)	0.205	0.321	0.640	0.522
Beaufort (2)	0.339	0.348	0.975	0.33
Beaufort (3)	0.368	0.382	0.964	0.335
Beaufort (4 or higher)	-0.665	0.488	-1.363	0.173

Parameter	Coefficient	SE	*z* value	*P* value
Distance[2]	6.422	7.124	0.901	0.367
Distance squared[2]	-0.203	10.159	-0.020	0.984
Distance cubed[2]	-7.581	6.552	-1.157	0.247
Vessel heading away from BSA	-0.879	0.578	-1.520	0.128
Vessel southbound	-0.226	0.635	-0.357	0.721
One vessel within 10 km from BSA	0.604	0.464	1.303	0.192
2+ vessels within 10 km from BSA	1.525	0.893	1.707	0.088
Tide (Flood)	0.000	0.247	0.002	0.999
Tide (High slack)	-0.039	0.290	-0.136	0.892
Tide (Ebb)	-0.002	0.256	-0.008	0.994
Time since shots fired[2]	-7.075	4.803	-1.473	0.141
Time since shots fired squared[2]	-3.682	5.017	-0.734	0.463
Time since shots fired cubed[2]	8.727	4.499	1.940	0.052
Hunting occurred within preceding 3 h	0.450	0.222	2.027	0.043
Small vessels present within SSA	0.237	0.164	1.443	0.149
Vessel distance[2] : Vessel heading away from BSA	4.932	9.561	0.516	0.606
Vessel distance squared[2] : Vessel heading away from BSA	-11.124	14.118	-0.788	0.431
Vessel distance cubed[2] : Vessel heading away from BSA	14.704	9.172	1.603	0.109
Vessel distance[2] : Vessel southbound	-10.282	9.892	-1.039	0.299
Vessel distance squared[2] : Vessel southbound	-3.380	13.742	-0.246	0.806
Vessel distance cubed[2] : Vessel southbound	6.201	9.013	0.688	0.491
Vessel heading away from BSA : Vessel southbound	0.669	0.871	0.768	0.443
Vessel distance[2] : Vessel heading away from BSA : Vessel southbound	-1.589	13.357	-0.119	0.905
Vessel distance squared[2] : Vessel heading away from BSA : Vessel southbound	9.607	19.057	0.504	0.614
Vessel distance cubed[2] : Vessel heading away from BSA : Vessel southbound	-4.830	12.412	-0.389	0.697

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Table C-7: Test statistics of mixed generalized linear model of group composition (presence of calves or yearlings; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	7.142	4	0.129
Group size	23.820	2	**<0.001**
Tide	2.080	3	0.556
Glare	7.189	2	**0.027**
Beaufort scale	5.378	4	0.251
Distance	1.432	3	0.698
Vessel direction relative to BSA	0.068	1	0.794
North- or southbound vessel	0.023	1	0.879
Vessel presence within 10 km from BSA	4.052	2	0.132
Time since last shooting event	$4.1 * 10^{-6}$	1	0.998
Hunting event within 3 h prior to observation	0.026	1	0.872
Presence of small vessels within the SSA	0.406	1	0.524
Distance:Vessel direction relative to BSA	1.723	3	0.632
Distance:North- or southbound vessel	0.853	3	0.837
Vessel direction relative to BSA:North- or southbound vessel	0.378	1	0.539
Distance:Vessel direction relative to BSA:North- or southbound vessel	14.251	3	**0.003**

Table C-8: Coefficient estimates for fixed effects in a mixed generalized linear model of group composition (presence of calves or yearlings; type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA, average group size)	0.241	0.424	0.569	0.569
Year (2015)	0.311	0.390	0.798	0.425
Year (2016)	0.839	0.354	2.370	0.018
Year (2017)	0.498	0.338	1.473	0.141
Year (2019)	0.640	0.343	1.864	0.062
Group size[1]	0.627	2.501	0.251	0.802
Group size squared[1]	12.989	2.671	4.863	<0.001
Glare (L)	-0.210	0.152	-1.382	0.167
Glare (S)	-0.646	0.259	-2.493	0.013
Beaufort (1)	-0.519	0.231	-2.247	0.025
Beaufort (2)	-0.521	0.255	-2.040	0.041
Beaufort (3)	-0.548	0.283	-1.934	0.053
Beaufort (4 or higher)	-0.403	0.358	-1.127	0.26

Parameter	Coefficient	SE	*z* value	*P* value
Distance¹	-11.552	8.068	-1.432	0.152
Distance squared¹	30.391	11.343	2.679	0.007
Distance cubed¹	-6.712	7.255	-0.925	0.355
Vessel heading away from BSA	1.160	0.500	2.320	0.02
Vessel southbound	1.213	0.552	2.200	0.028
One vessel within 10 km from BSA	-0.836	0.428	-1.951	0.051
2+ vessels within 10 km from BSA	-0.456	0.779	-0.586	0.558
Tide (Flood)	-0.032	0.187	-0.171	0.864
Tide (High slack)	0.071	0.217	0.326	0.745
Tide (Ebb)	0.158	0.189	0.837	0.402
Time since shots fired²	0.0002	0.089	0.002	0.998
Hunting occurred within preceding 3 h	-0.020	0.127	-0.161	0.872
Small vessels present within SSA	-0.085	0.134	-0.637	0.524
Vessel distance¹ : Vessel heading away from BSA	10.987	9.129	1.204	0.229
Vessel distance squared¹ : Vessel heading away from BSA	-35.823	13.016	-2.752	0.006
Vessel distance cubed¹ : Vessel heading away from BSA	1.383	8.518	0.162	0.871
Vessel distance¹ : Vessel southbound	16.226	9.503	1.707	0.088
Vessel distance squared¹ : Vessel southbound	-41.047	13.549	-3.030	0.002
Vessel distance cubed¹ : Vessel southbound	1.760	8.763	0.201	0.841
Vessel heading away from BSA : Vessel southbound	-1.900	0.749	-2.536	0.011
Vessel distance¹ : Vessel heading away from BSA : Vessel southbound	-25.067	11.683	-2.146	0.032
Vessel distance squared¹ : Vessel heading away from BSA : Vessel southbound	52.817	16.851	3.134	0.002
Vessel distance cubed¹ : Vessel heading away from BSA : Vessel southbound	6.008	11.024	0.545	0.586

¹ = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable. ² = Variable was standardized prior to modeling.

Group Spread

Table C-9: Test statistics of mixed generalized linear model of group spread (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	20.577	4	**<0.001**
Group size	39.792	1	**<0.001**
Glare	0.818	2	0.664
Beaufort scale	1.189	4	0.880
Tide	1.287	3	0.732
Distance	0.966	2	0.617

Parameter	Chi squared	Df	*P* value
Vessel direction relative to BSA	0.337	1	0.562
North- or southbound vessel	0.458	1	0.499
Vessel presence within 10 km from BSA	4.74	2	0.093
Time since last shooting event	1.812	1	0.178
Hunting event within 3 h prior to observation	5.19	1	**0.023**
Presence of small vessels within the SSA	0.462	1	0.497
Distance:Vessel direction relative to BSA	3.699	2	0.157
Distance:North- or southbound vessel	1.573	2	0.455
Vessel direction relative to BSA:North- or southbound vessel	0.455	1	0.500
Distance:Vessel direction relative to BSA:North- or southbound vessel	2.175	2	0.337

Table C-10: Coefficient estimates for fixed effects in a mixed generalized linear model of group spread (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA)	-2.455	0.538	-4.564	<0.001
Year (2015)	1.386	0.491	2.821	0.005
Year (2016)	0.956	0.454	2.105	0.035
Year (2017)	1.638	0.443	3.701	<0.001
Year (2019)	1.611	0.441	3.653	<0.001
N[1]	0.257	0.041	6.308	<0.001
Glare (L)	-0.067	0.185	-0.361	0.718
Glare (S)	0.205	0.276	0.740	0.459
Beaufort (1)	0.240	0.280	0.859	0.39
Beaufort (2)	0.227	0.297	0.764	0.445
Beaufort (3)	0.190	0.332	0.572	0.567
Beaufort (4 or higher)	0.011	0.418	0.026	0.979
Distance[2]	14.485	7.580	1.911	0.056
Distance squared[2]	-21.535	10.671	-2.018	0.044
Vessel heading away from BSA	-0.798	0.486	-1.641	0.101
Vessel southbound	-0.925	0.554	-1.670	0.095
One vessel within 10 km from BSA	0.770	0.416	1.851	0.064
2+ vessels within 10 km from BSA	1.500	0.805	1.864	0.062
Tide (Flood)	-0.231	0.208	-1.113	0.266
Tide (High slack)	-0.160	0.250	-0.641	0.522
Tide (Ebb)	-0.124	0.214	-0.578	0.563
Time since shots fired[1]	0.138	0.103	1.346	0.178

Parameter	Coefficient	SE	*z* value	*P* value
Hunting occurred within preceding 3 h	-0.348	0.153	-2.278	0.023
Small vessels present within SSA	-0.095	0.139	-0.679	0.497
Vessel distance² : Vessel heading away from BSA	-19.044	8.759	-2.174	0.03
Vessel distance squared² : Vessel heading away from BSA	17.385	12.621	1.377	0.168
Vessel distance² : Vessel southbound	-13.581	9.285	-1.463	0.144
Vessel distance squared² : Vessel southbound	21.298	13.016	1.636	0.102
Vessel heading away from BSA : Vessel southbound	0.890	0.733	1.215	0.224
Vessel distance² : Vessel heading away from BSA : Vessel southbound	13.335	11.640	1.146	0.252
Vessel distance squared² : Vessel heading away from BSA : Vessel southbound	-17.826	16.490	-1.081	0.28

¹ = Variable was standardized prior to modeling. ² = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Formation

Table C-11: Test statistics of mixed generalized linear model of group formation (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	24.987	4	**<0.001**
Group size	327.943	1	**<0.001**
Glare	19.455	2	**<0.001**
Beaufort scale	11.199	4	**0.024**
Tide	3.051	3	0.384
Distance	3.409	2	0.182
Vessel direction relative to BSA	0.126	1	0.723
North- or southbound vessel	0.114	1	0.736
Vessel presence within 10 km from BSA	0.647	2	0.723
Time since last shooting event	4.116	3	0.249
Hunting event within 3 h prior to observation	2.848	1	0.092
Presence of small vessels within the SSA	0.322	1	0.570
Distance:Vessel direction relative to BSA	0.52	2	0.771
Distance:North- or southbound vessel	1.494	2	0.474
Vessel direction relative to BSA:North- or southbound vessel	0.335	1	0.563
Distance:Vessel direction relative to BSA:North- or southbound vessel	5.387	2	0.068

Table C-12: Coefficient estimates for fixed effects in a mixed generalized linear model of group formation (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA, average group size)	-2.200	0.439	-5.008	<0.001
Year (2015)	0.985	0.387	2.548	0.011
Year (2016)	1.186	0.360	3.297	0.001
Year (2017)	1.309	0.342	3.827	<0.001
Year (2019)	1.600	0.345	4.639	<0.001
N[1]	0.914	0.050	18.109	<0.001
Glare (L)	0.105	0.159	0.661	0.509
Glare (S)	1.065	0.242	4.410	<0.001
Beaufort (1)	0.131	0.241	0.542	0.587
Beaufort (2)	0.342	0.255	1.341	0.18
Beaufort (3)	-0.315	0.285	-1.107	0.268
Beaufort (4 or higher)	0.100	0.340	0.293	0.769
Distance[2]	8.000	7.449	1.074	0.283
Distance squared[2]	-15.181	10.616	-1.430	0.153
Vessel heading away from BSA	-0.363	0.513	-0.707	0.479
Vessel southbound	-0.396	0.549	-0.723	0.47
One vessel within 10 km from BSA	0.342	0.425	0.804	0.421
2+ vessels within 10 km from BSA	0.325	0.781	0.416	0.677
Tide (Flood)	-0.188	0.188	-0.998	0.318
Tide (High slack)	-0.376	0.225	-1.669	0.095
Tide (Ebb)	-0.259	0.192	-1.353	0.176
Time since shots fired[2]	0.362	3.429	0.105	0.916
Time since shots fired squared[2]	-6.393	4.136	-1.546	0.122
Time since shots fired cubed[2]	6.497	3.691	1.760	0.078
Hunting occurred within preceding 3 h	0.298	0.177	1.688	0.091
Small vessels present within SSA	-0.081	0.143	-0.567	0.57
Vessel distance[2] : Vessel heading away from BSA	-17.383	9.278	-1.873	0.061
Vessel distance squared[2] : Vessel heading away from BSA	2.273	13.250	0.172	0.864
Vessel distance[2] : Vessel southbound	-9.258	9.505	-0.974	0.33
Vessel distance squared[2] : Vessel southbound	5.398	13.273	0.407	0.684
Vessel heading away from BSA : Vessel southbound	0.107	0.769	0.140	0.889
Vessel distance[2] : Vessel heading away from BSA : Vessel southbound	27.707	12.408	2.233	0.026

Parameter	Coefficient	SE	*z* value	*P* value
Vessel distance squared² : Vessel heading away from BSA : Vessel southbound	8.707	17.529	0.497	0.619

¹ = Variable was standardized prior to modeling. ² = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Direction

Table C-13: Test statistics of mixed generalized linear model of group direction (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	9.295	4	0.054
Group size	1.879	1	0.170
Glare	3.663	2	0.160
Beaufort scale	17.415	4	**0.002**
Tide	0.359	3	0.949
Distance	3.850	1	**0.050**
Vessel direction relative to BSA	0.131	1	0.717
North- or southbound vessel	1.196	1	0.274
Vessel presence within 10 km from BSA	0.670	2	0.715
Time since last shooting event	3.091	2	0.213
Hunting event within 3 h prior to observation	1.961	1	0.161
Presence of small vessels within the SSA	0.065	1	0.799
Distance:Vessel direction relative to BSA	0.208	1	0.648
Distance:North- or southbound vessel	0.702	1	0.402
Vessel direction relative to BSA:North- or southbound vessel	3.293	1	0.070
Distance:Vessel direction relative to BSA:North- or southbound vessel	1.953	1	0.162

Table C-14: Coefficient estimates for fixed effects in a mixed generalized linear model of group direction (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA)	3.654	2.498	1.463	0.144
Year (2015)	2.062	2.058	1.002	0.316
Year (2016)	-2.240	1.963	-1.141	0.254
Year (2017)	-1.705	1.997	-0.854	0.393
Year (2019)	-2.050	1.924	-1.065	0.287
N¹	0.188	0.137	1.371	0.17
Glare (L)	-1.040	0.845	-1.231	0.218
Glare (S)	1.229	1.278	0.962	0.336

Parameter	Coefficient	SE	*z* value	*P* value
Beaufort (1)	-0.305	1.579	-0.193	0.847
Beaufort (2)	2.151	1.712	1.256	0.209
Beaufort (3)	4.294	1.837	2.338	0.019
Beaufort (4 or higher)	1.168	2.256	0.518	0.605
Distance[1]	-1.265	0.864	-1.465	0.143
Vessel heading away from BSA	3.051	1.611	1.894	0.058
Vessel southbound	0.157	2.019	0.078	0.938
One vessel within 10 km from BSA	0.884	1.377	0.642	0.521
2+ vessels within 10 km from BSA	2.238	3.177	0.704	0.481
Tide (Flood)	0.220	1.001	0.220	0.826
Tide (High slack)	0.274	1.184	0.231	0.817
Tide (Ebb)	0.585	1.053	0.555	0.579
Time since shots fired[2]	-15.387	18.473	-0.833	0.405
Time since shots fired squared[2]	27.107	18.763	1.445	0.149
Hunting occurred within preceding 3 h	1.339	0.956	1.400	0.161
Small vessels present within SSA	-0.136	0.532	-0.255	0.799
Vessel distance[1] : Vessel heading away from BSA	1.526	1.260	1.211	0.226
Vessel distance[1] : Vessel southbound	-0.134	1.298	-0.103	0.918
Vessel heading away from BSA : Vessel southbound	-5.896	2.603	-2.265	0.024
Vessel distance[1] : Vessel heading away from BSA : Vessel southbound	-2.923	2.091	-1.397	0.162

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Travel Speed

Table C-15: Test statistics of mixed generalized linear model of travel speed (slow travel vs. medium travel speed; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	18.353	4	**0.001**
Group size	58.404	1	**<0.001**
Glare	0.667	2	0.716
Beaufort scale	10.571	4	**0.032**
Tide	4.182	3	0.242
Distance	1.323	1	0.250
Vessel direction relative to BSA	0.001	1	0.982
North- or southbound vessel	2.036	1	0.154
Vessel presence within 10 km from BSA	0.246	2	0.884
Time since last shooting event	1.462	1	0.227
Hunting event within 3 h prior to observation	1.237	1	0.266

Parameter	Chi squared	Df	*P* value
Presence of small vessels within the SSA	1.468	1	0.226
Distance:Vessel direction relative to BSA	0.144	1	0.704
Distance:North- or southbound vessel	2.449	1	0.118
Vessel direction relative to BSA:North- or southbound vessel	1.53	1	0.216
Distance:Vessel direction relative to BSA:North- or southbound vessel	0.126	1	0.723

Table C-16: Coefficient estimates for fixed effects in a mixed generalized linear model of travel speed (slow travel vs. medium travel speed; type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA, average group size)	-1.270	0.881	-1.443	0.149
Year (2015)	1.057	0.838	1.261	0.207
Year (2016)	1.642	0.723	2.271	0.023
Year (2017)	1.483	0.712	2.083	0.037
Year (2019)	2.648	0.711	3.723	<0.001
N[1]	-0.604	0.079	-7.642	<0.001
Glare (L)	-0.260	0.325	-0.798	0.425
Glare (S)	0.012	0.464	0.026	0.98
Beaufort (1)	-0.708	0.503	-1.407	0.159
Beaufort (2)	-1.394	0.549	-2.541	0.011
Beaufort (3)	-1.537	0.606	-2.534	0.011
Beaufort (4 or higher)	-1.305	0.721	-1.809	0.07
Distance[1]	-0.088	0.436	-0.202	0.84
Vessel heading away from BSA	-0.588	0.698	-0.842	0.4
Vessel southbound	0.236	0.787	0.300	0.764
One vessel within 10 km from BSA	-0.271	0.559	-0.485	0.628
2+ vessels within 10 km from BSA	-0.314	1.353	-0.232	0.816
Tide (Flood)	-0.133	0.369	-0.360	0.719
Tide (High slack)	-0.758	0.438	-1.732	0.083
Tide (Ebb)	-0.381	0.377	-1.010	0.312
Time since shots fired[2]	0.231	0.191	1.209	0.227
Time since shots fired squared[2]	-0.315	0.283	-1.112	0.266
Hunting occurred within preceding 3 h	0.284	0.235	1.212	0.226
Small vessels present within SSA	-0.010	0.593	-0.018	0.986
Vessel distance[1] : Vessel heading away from BSA	0.908	0.636	1.427	0.154
Vessel distance[1] : Vessel southbound	1.130	1.006	1.123	0.261
Vessel heading away from BSA : Vessel southbound	-0.297	0.838	-0.355	0.723

Parameter	Coefficient	SE	*z* value	*P* value
Vessel distance[1] : Vessel heading away from BSA : Vessel southbound	-1.270	0.881	-1.443	0.149

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Distance from Bruce Head Shore

Table C-17: Test statistics of mixed generalized linear model of distance from Bruce Head shore (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	13.673	4	**0.008**
Group size	13.012	1	**<0.001**
Glare	3.715	2	0.156
Beaufort scale	14.131	4	**0.007**
Tide	1.143	3	0.767
Distance	7.185	2	**0.028**
Vessel direction relative to BSA	1.511	1	0.219
North- or southbound vessel	0.513	1	0.474
Vessel presence within 10 km from BSA	4.218	2	0.121
Time since last shooting event	5.903	2	0.052
Hunting event within 3 h prior to observation	0.027	1	0.870
Presence of small vessels within the SSA	1.701	1	0.192
Distance:Vessel direction relative to BSA	8.622	2	**0.013**
Distance:North- or southbound vessel	0.402	2	0.818
Vessel direction relative to BSA:North- or southbound vessel	0.540	1	0.463
Distance:Vessel direction relative to BSA:North- or southbound vessel	4.277	2	0.118

Table C-18: Coefficient estimates for fixed effects in a mixed generalized linear model of distance from Bruce Head shore (type I *P* values)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 10 km from BSA, Tide = low slack, no hunting within preceding 3 h, no small vessels present within SSA)	-1.094	0.802	-1.365	0.172
Year (2015)	-2.053	0.823	-2.495	0.013
Year (2016)	-0.243	0.681	-0.357	0.721
Year (2017)	0.096	0.680	0.141	0.888
Year (2019)	0.149	0.663	0.225	0.822
N[1]	-0.190	0.053	-3.607	<0.001

Parameter	Coefficient	SE	*z* value	*P* value
Glare (L)	-0.556	0.289	-1.926	0.054
Glare (S)	-0.183	0.446	-0.409	0.682
Beaufort (1)	0.087	0.436	0.198	0.843
Beaufort (2)	-0.343	0.482	-0.712	0.476
Beaufort (3)	-1.200	0.547	-2.195	0.028
Beaufort (4 or higher)	-1.038	0.670	-1.549	0.121
Distance[1]	0.012	0.319	0.037	0.971
Vessel heading away from BSA	-0.075	0.377	-0.200	0.841
Vessel southbound	0.214	0.331	0.647	0.517
One vessel within 10 km from BSA	-3.106	8.019	-0.387	0.698
2+ vessels within 10 km from BSA	-32.836	10.704	-3.068	0.002
Tide (Flood)	-1.155	0.653	-1.767	0.077
Tide (High slack)	0.551	0.771	0.714	0.475
Tide (Ebb)	0.802	0.530	1.515	0.130
Time since shots fired[1]	-1.363	1.539	-0.886	0.376
Hunting occurred within preceding 3 h	-2.362	6.635	-0.356	0.722
Small vessels present within SSA	-15.987	6.603	-2.421	0.015
Vessel distance[1] : Vessel heading away from BSA	0.048	0.293	0.165	0.869
Vessel distance[1] : Vessel southbound	0.228	0.175	1.304	0.192
Vessel heading away from BSA : Vessel southbound	9.092	10.340	0.879	0.379
Vessel distance[1] : Vessel heading away from BSA : Vessel southbound	32.875	14.351	2.291	0.022

[1] = Variable was standardized prior to modeling.

APPENDIX D

Model Diagnostics

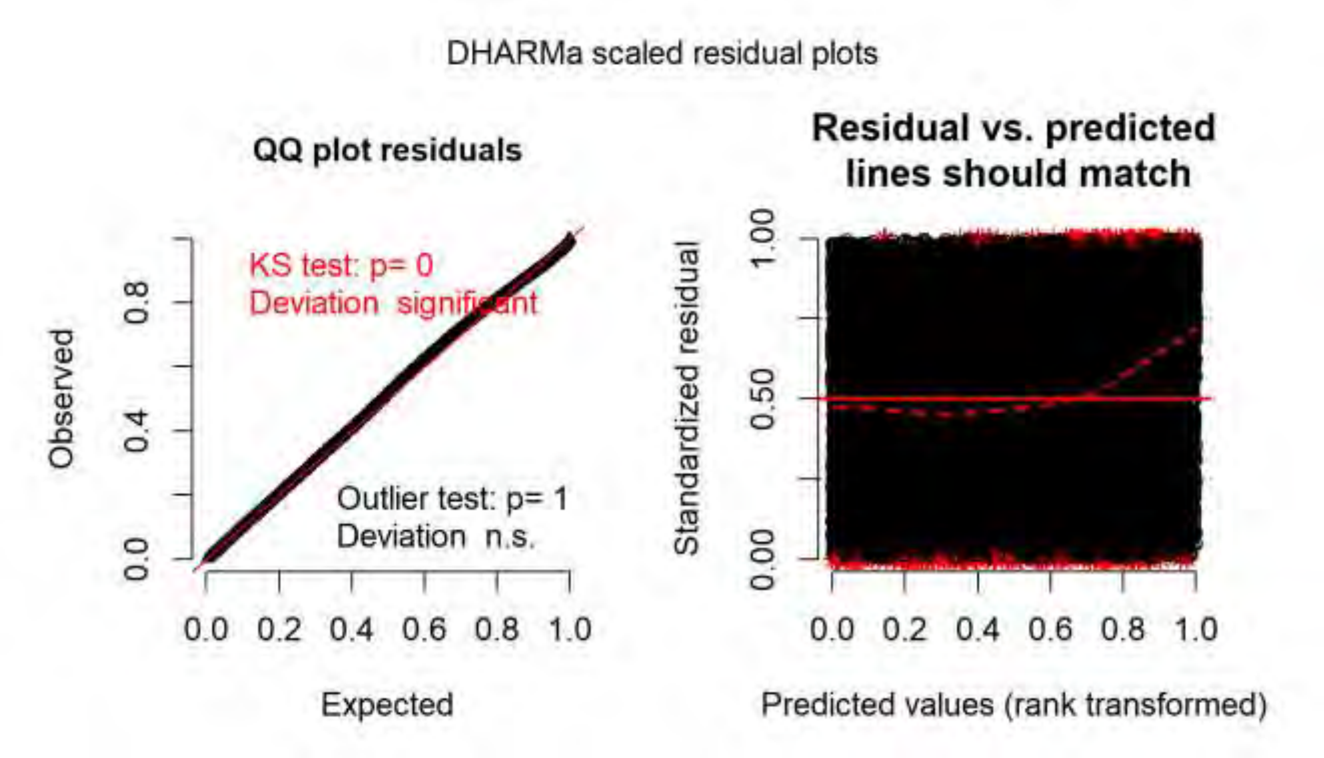


Figure D-1: Residual diagnostics for RAD model – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

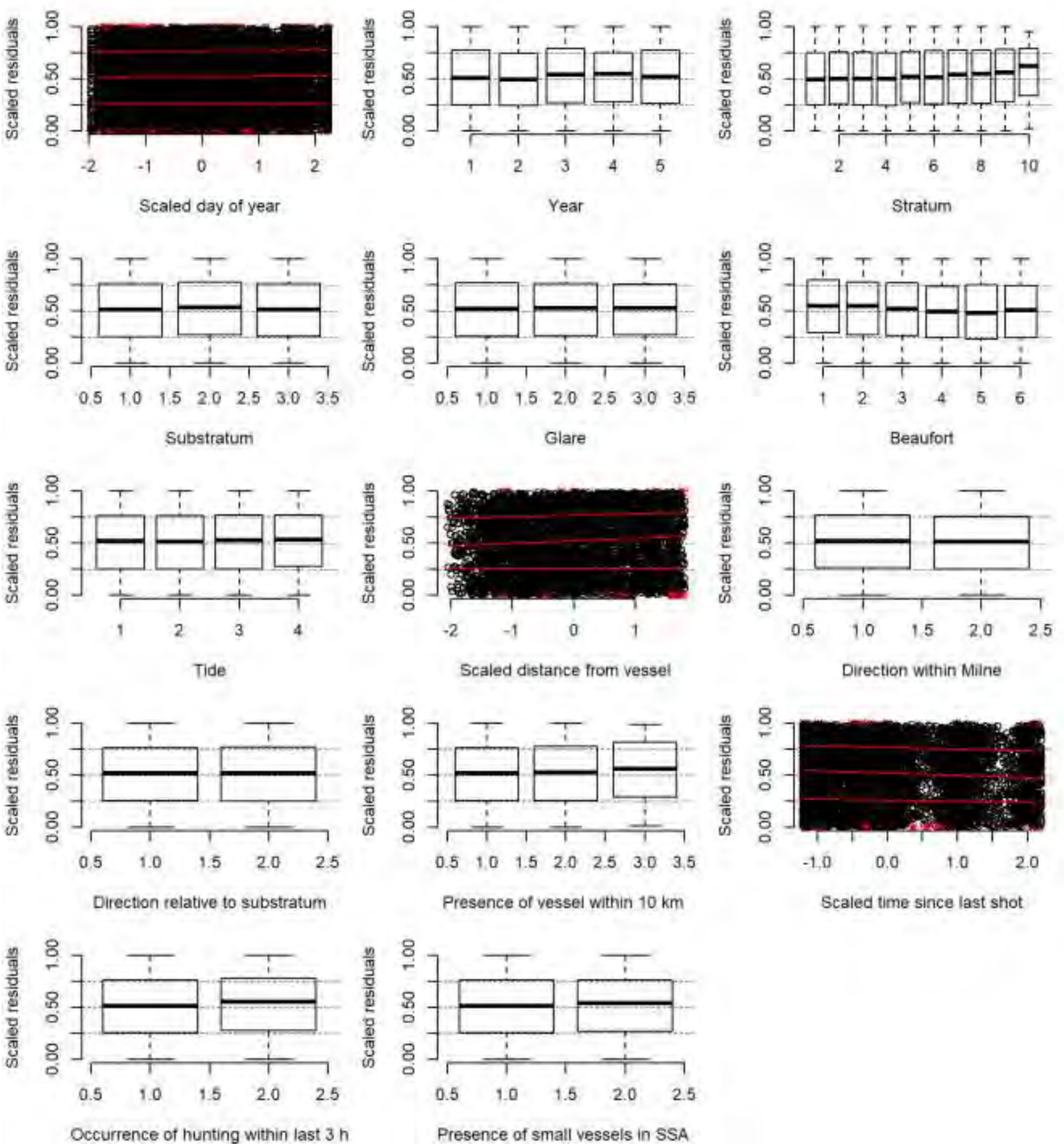


Figure D-2: Residual diagnostics for RAD model – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

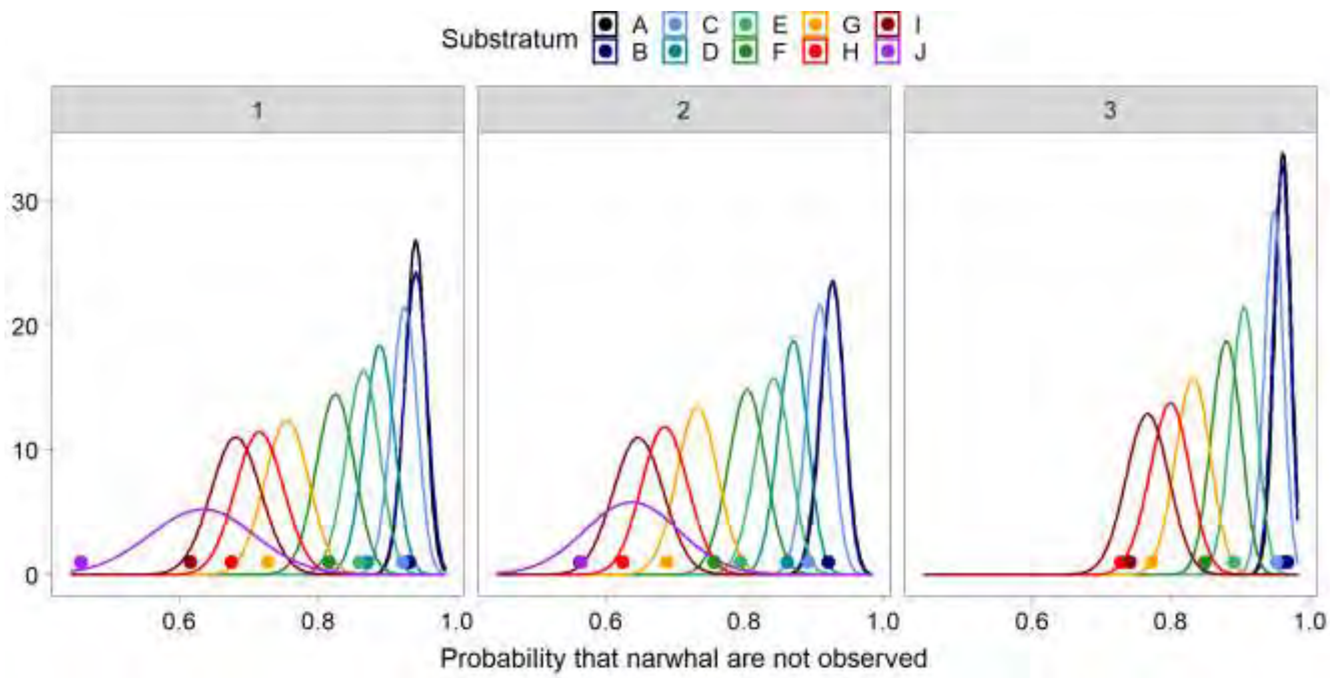


Figure D-3: RAD model diagnostics – simulated zero counts. Each panel represents a different substratum (1, 2, or 3). Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

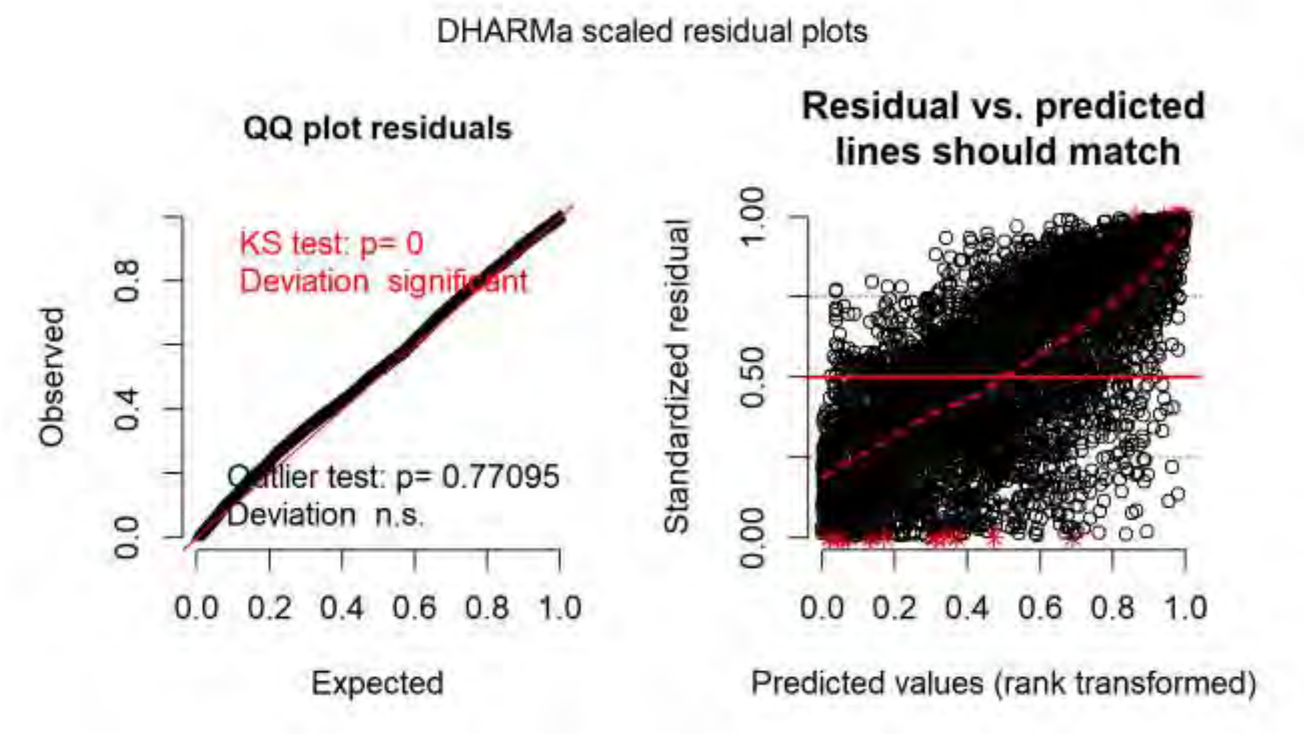


Figure D-4: Residual diagnostics for model of group size – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

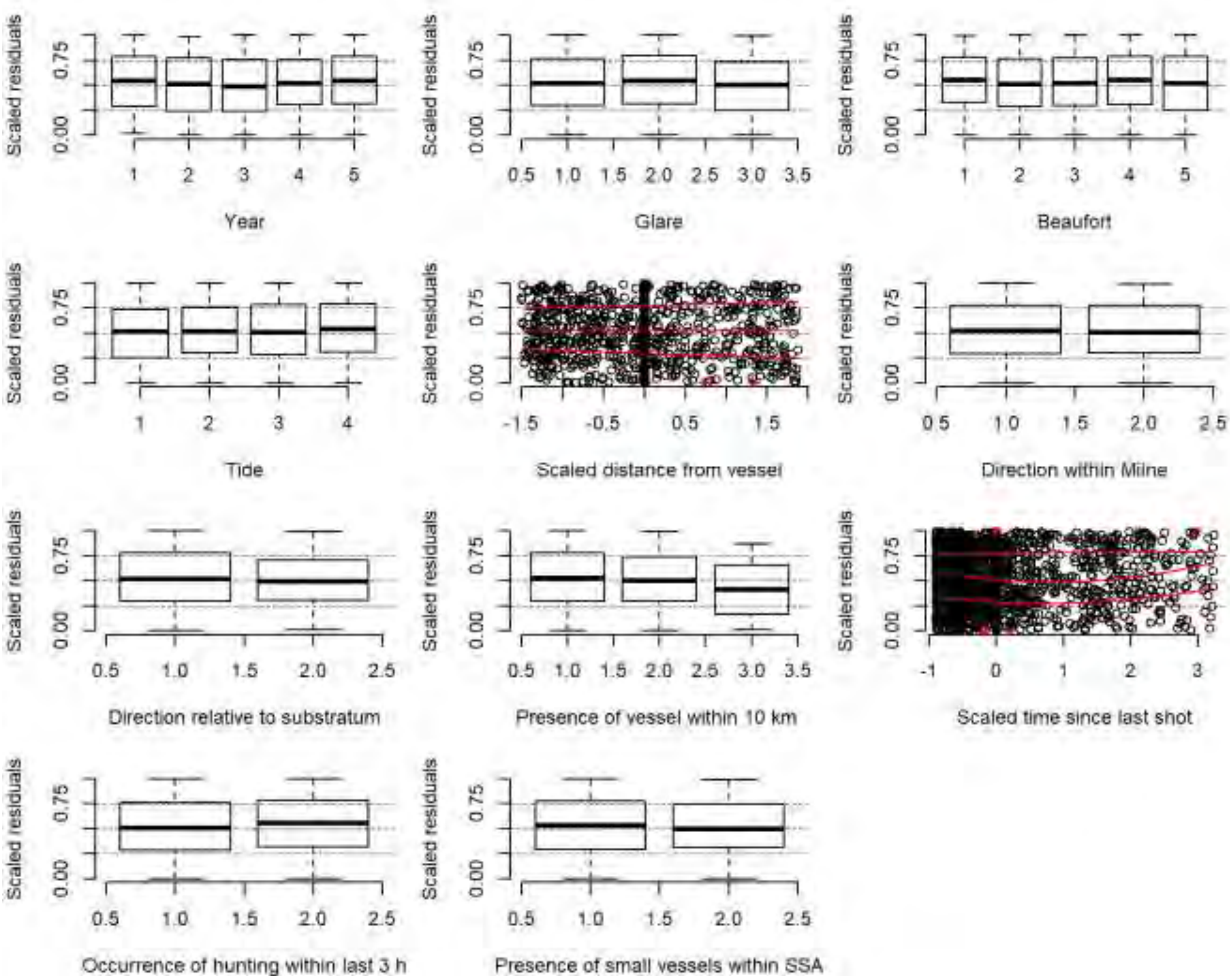


Figure D-5: Residual diagnostics for model of group size – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

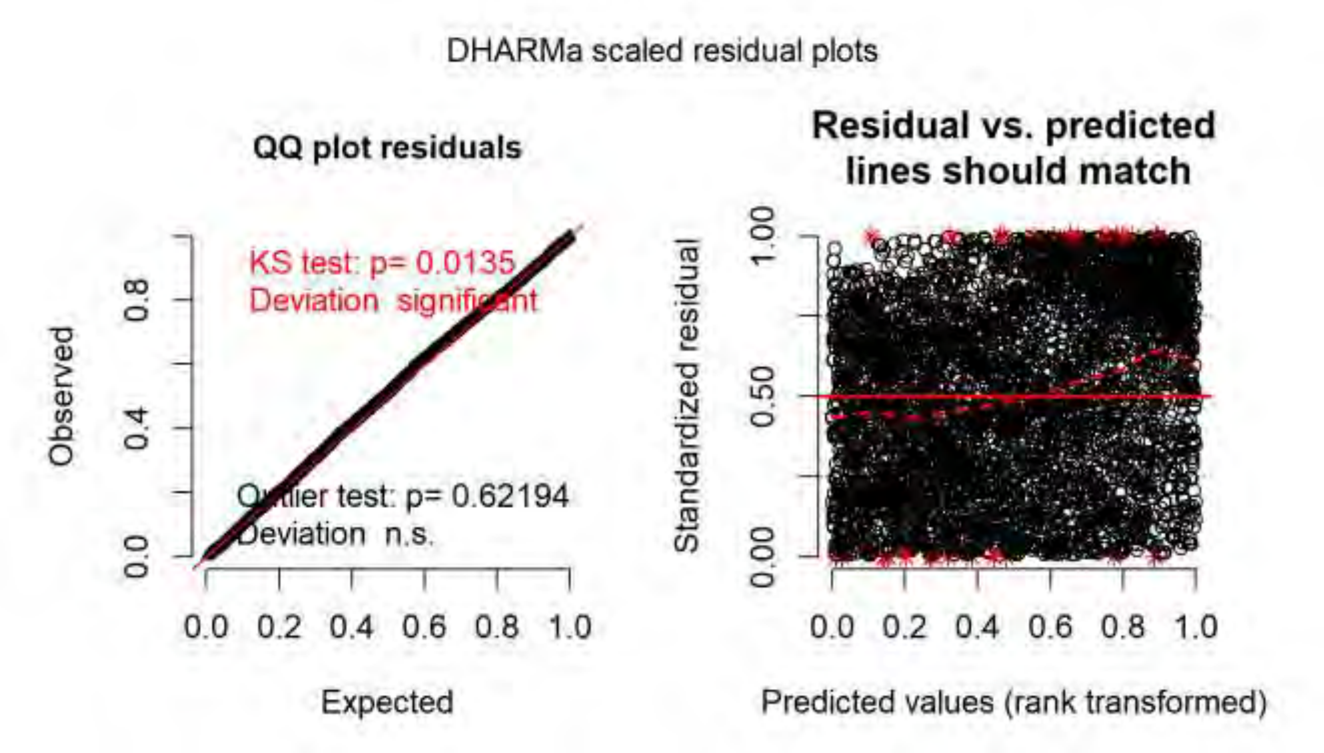


Figure D-6: Residual diagnostics for model of group composition – presence of tusks– QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

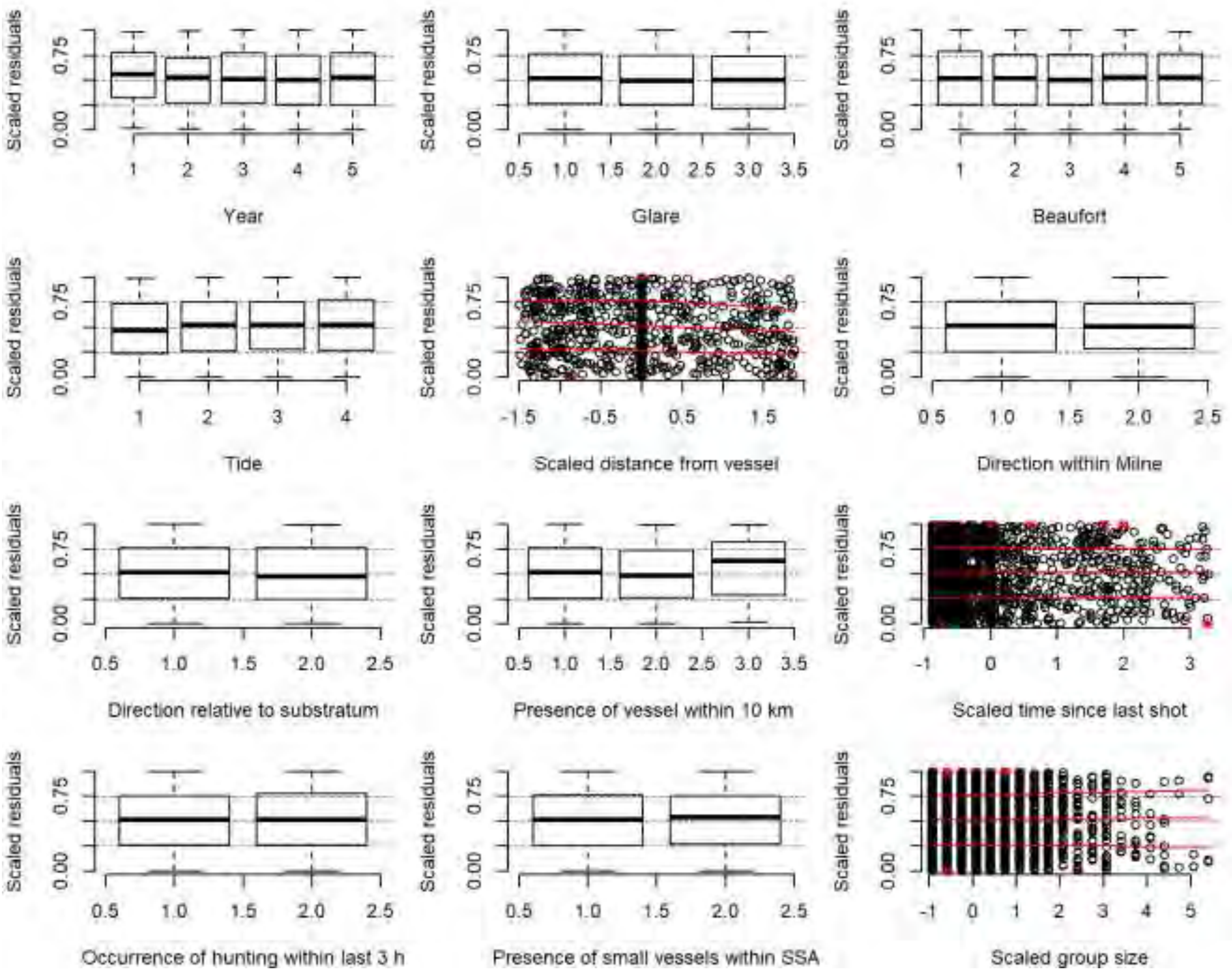


Figure D-7: Residual diagnostics for model of group composition – presence of tusks – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

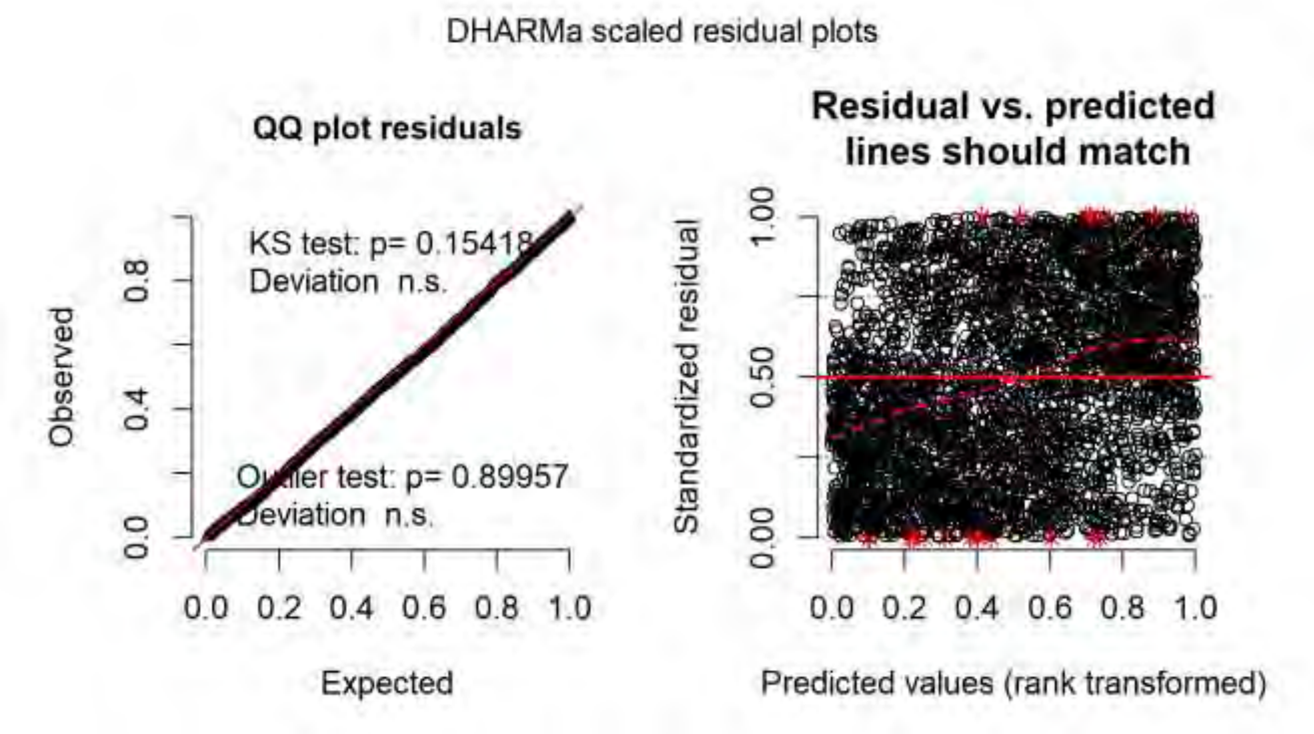


Figure D-8: Residual diagnostics for model of group composition – presence of calves and yearlings – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

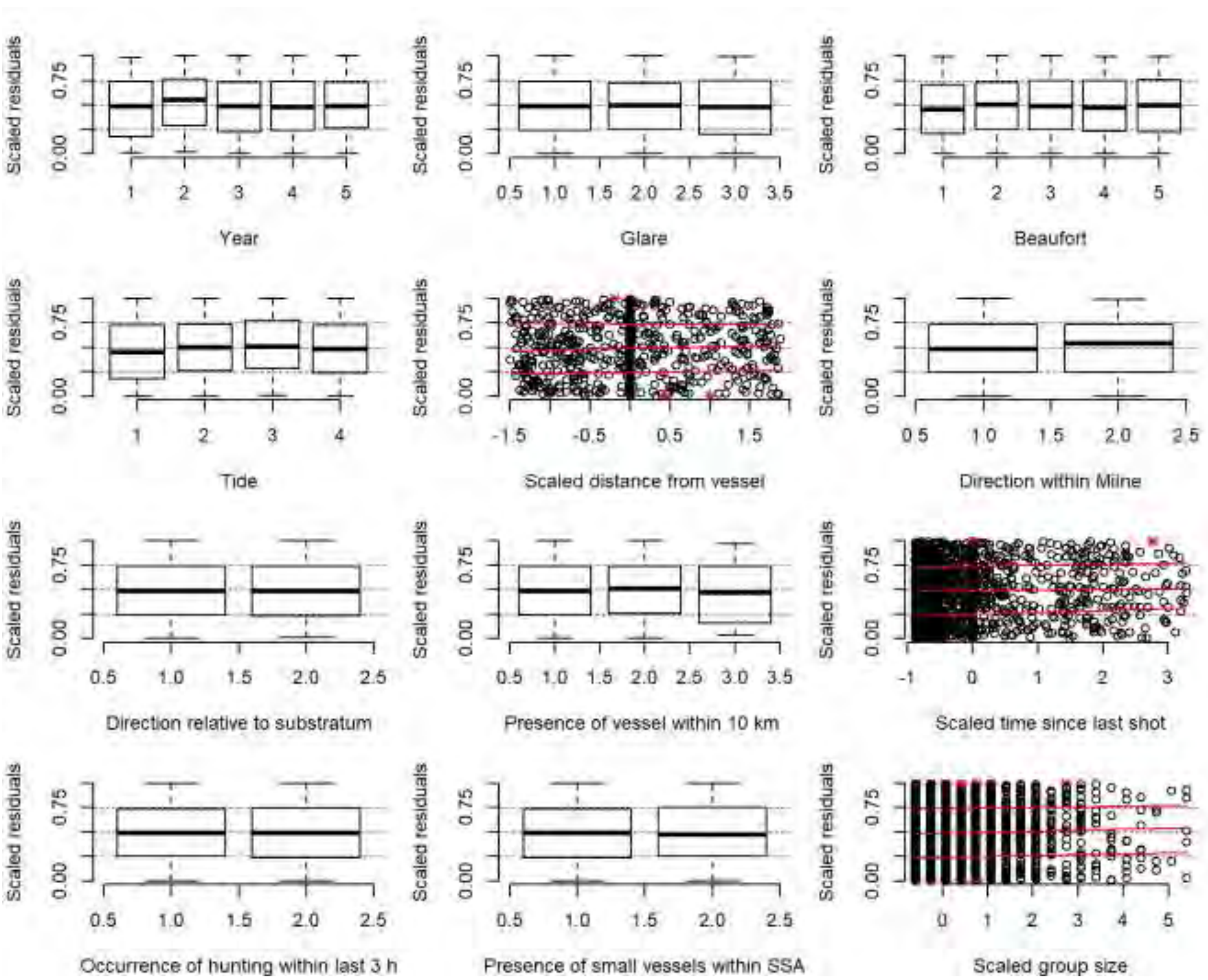


Figure D-9: Residual diagnostics for model of group composition – presence of calves and yearlings – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

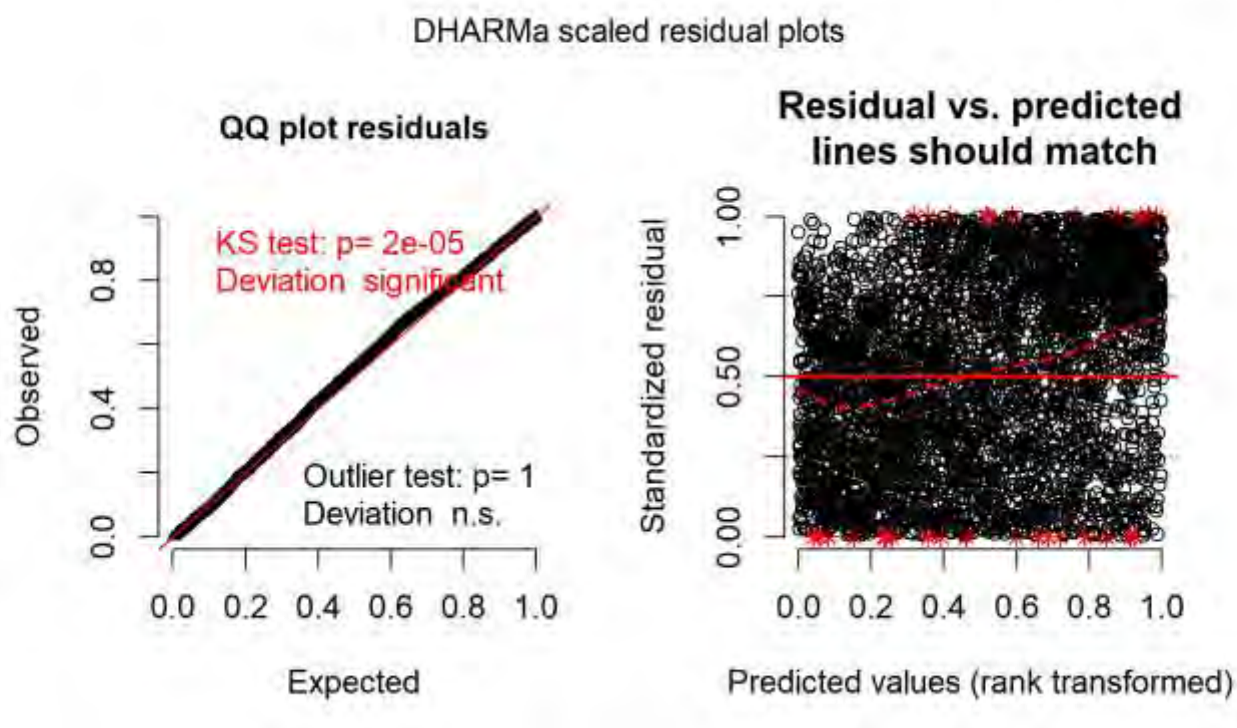


Figure D-10: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

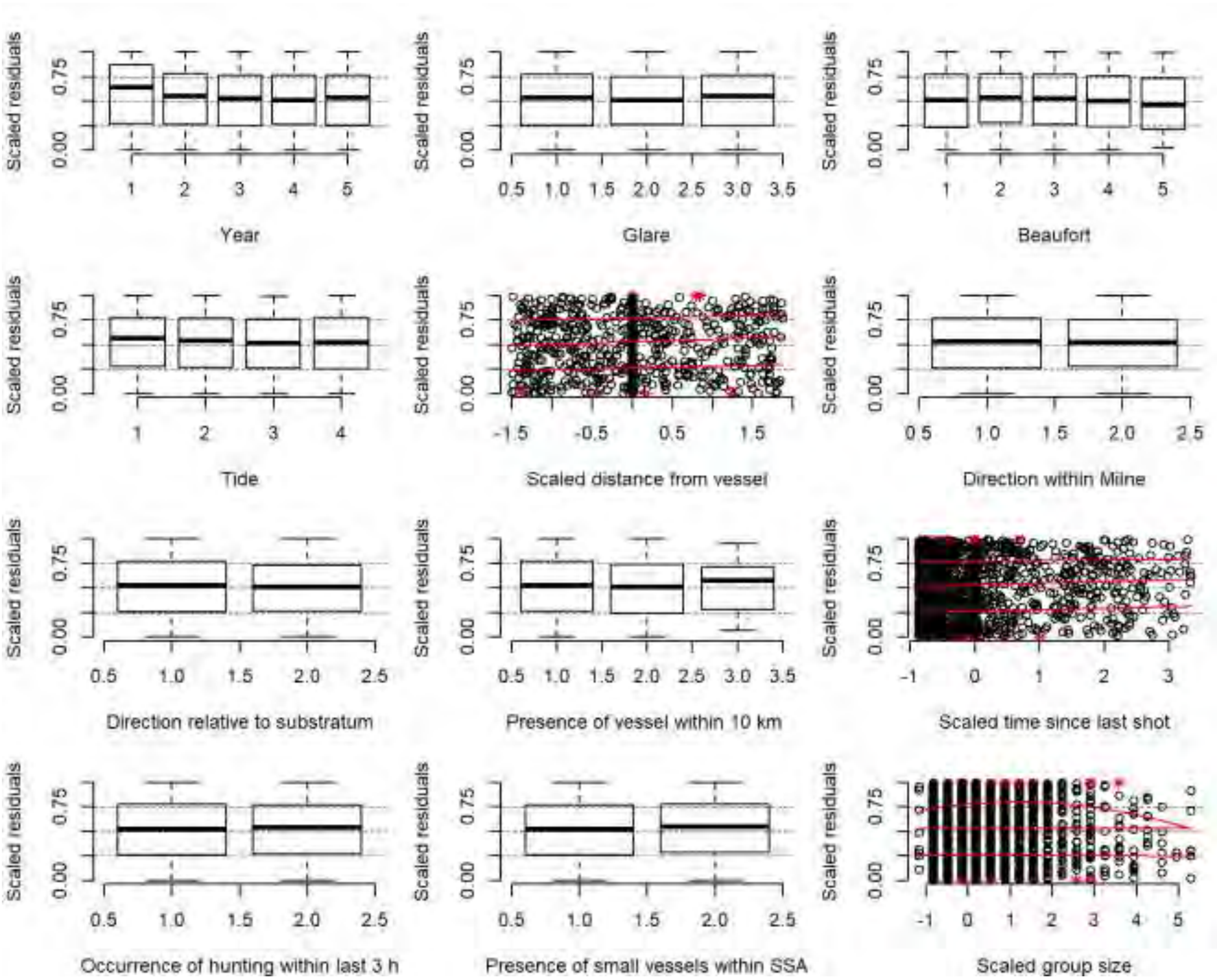


Figure D-11: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

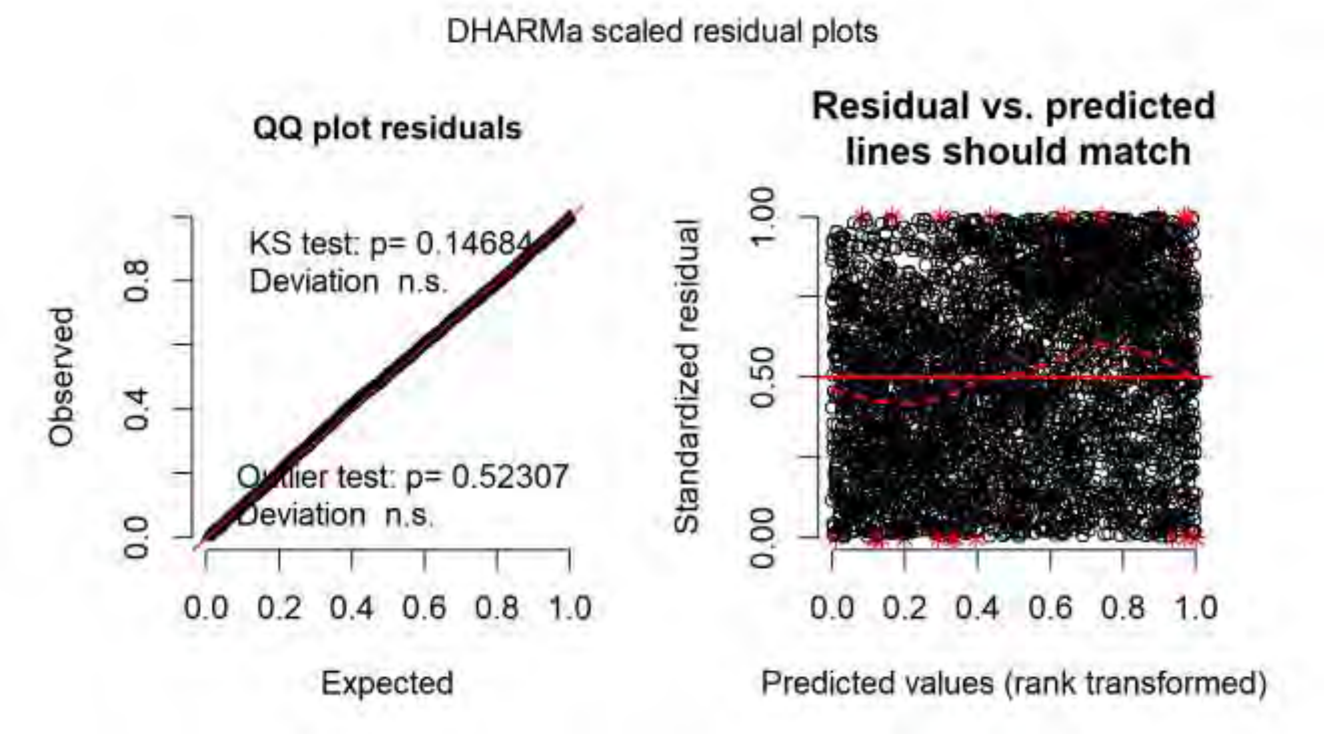


Figure D-12: Residual diagnostics for model of groups observed in non-parallel formation – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

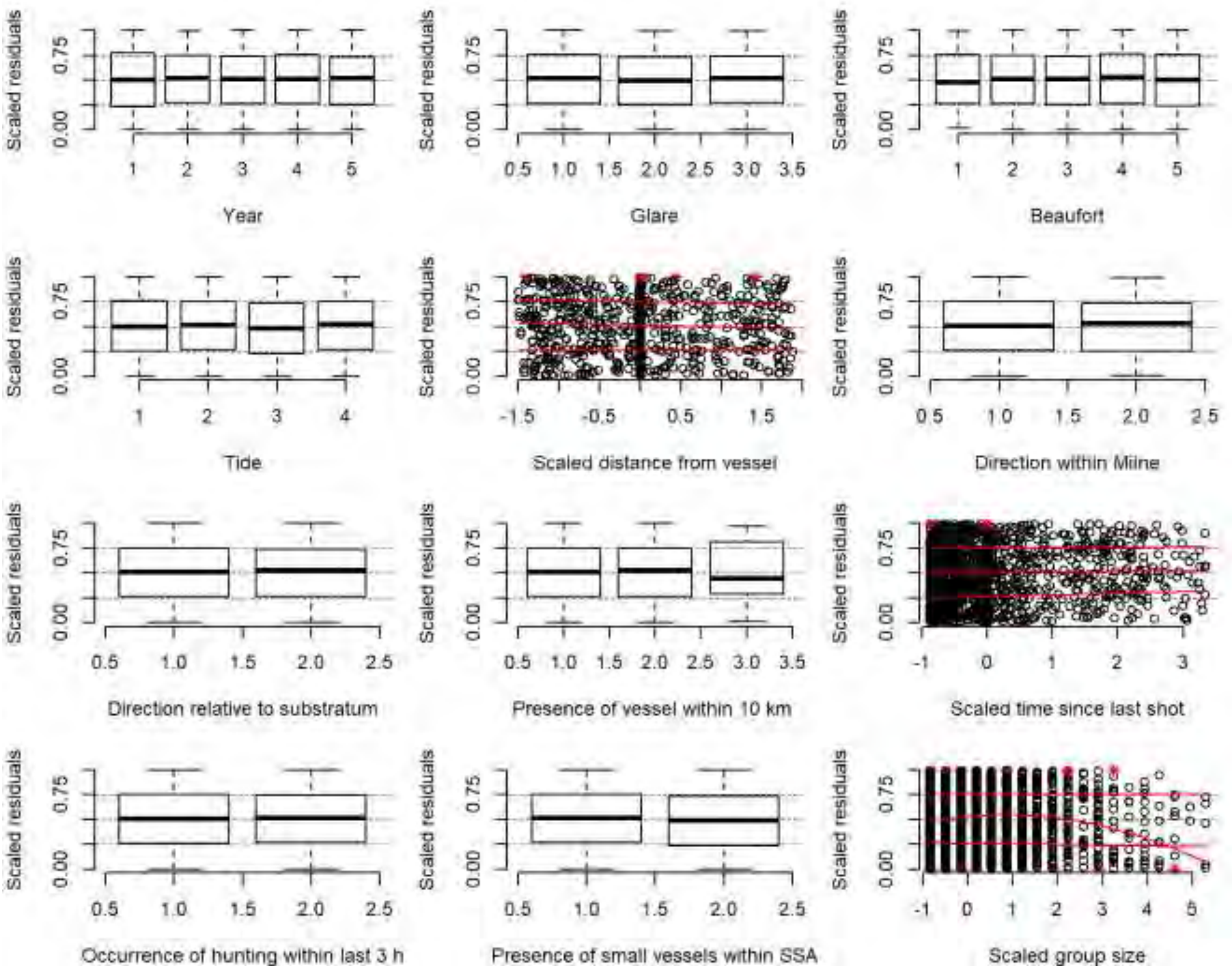


Figure D-13: Residual diagnostics for model of groups observed in non-parallel formation – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

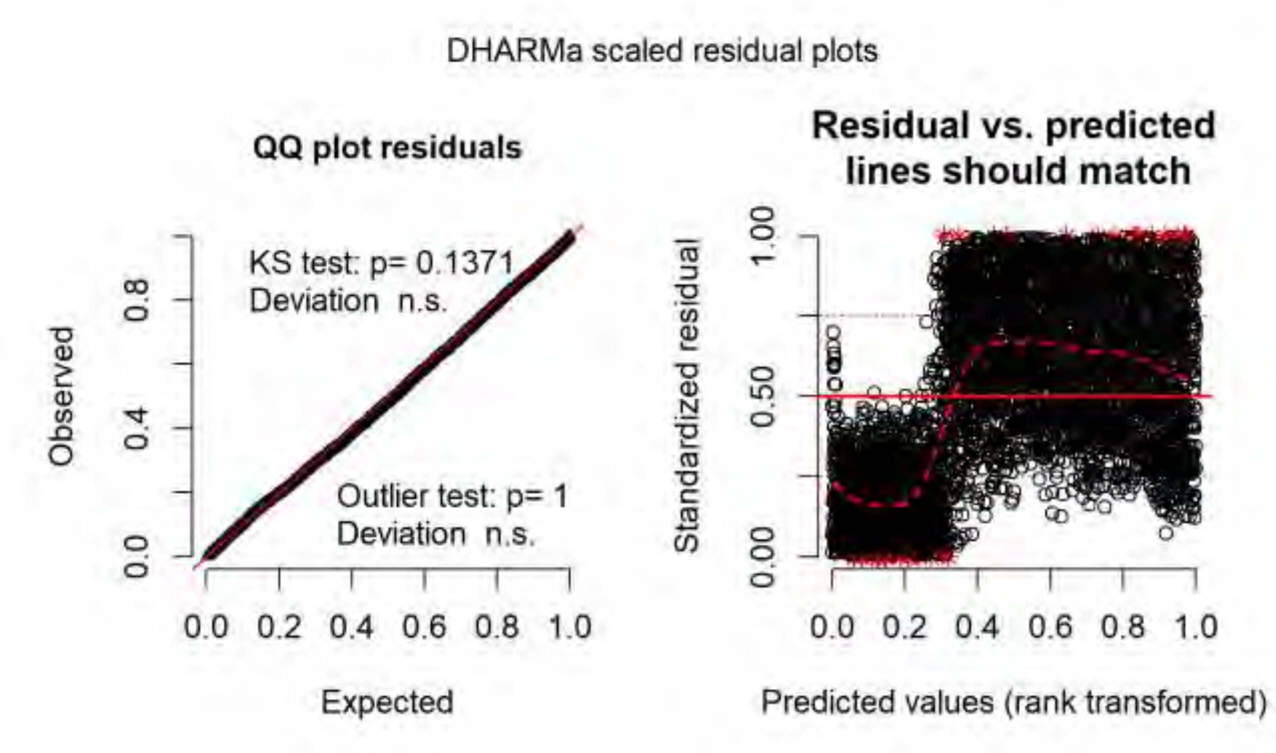


Figure D-14: Residual diagnostics for model of groups observed travelling south (rather than north) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

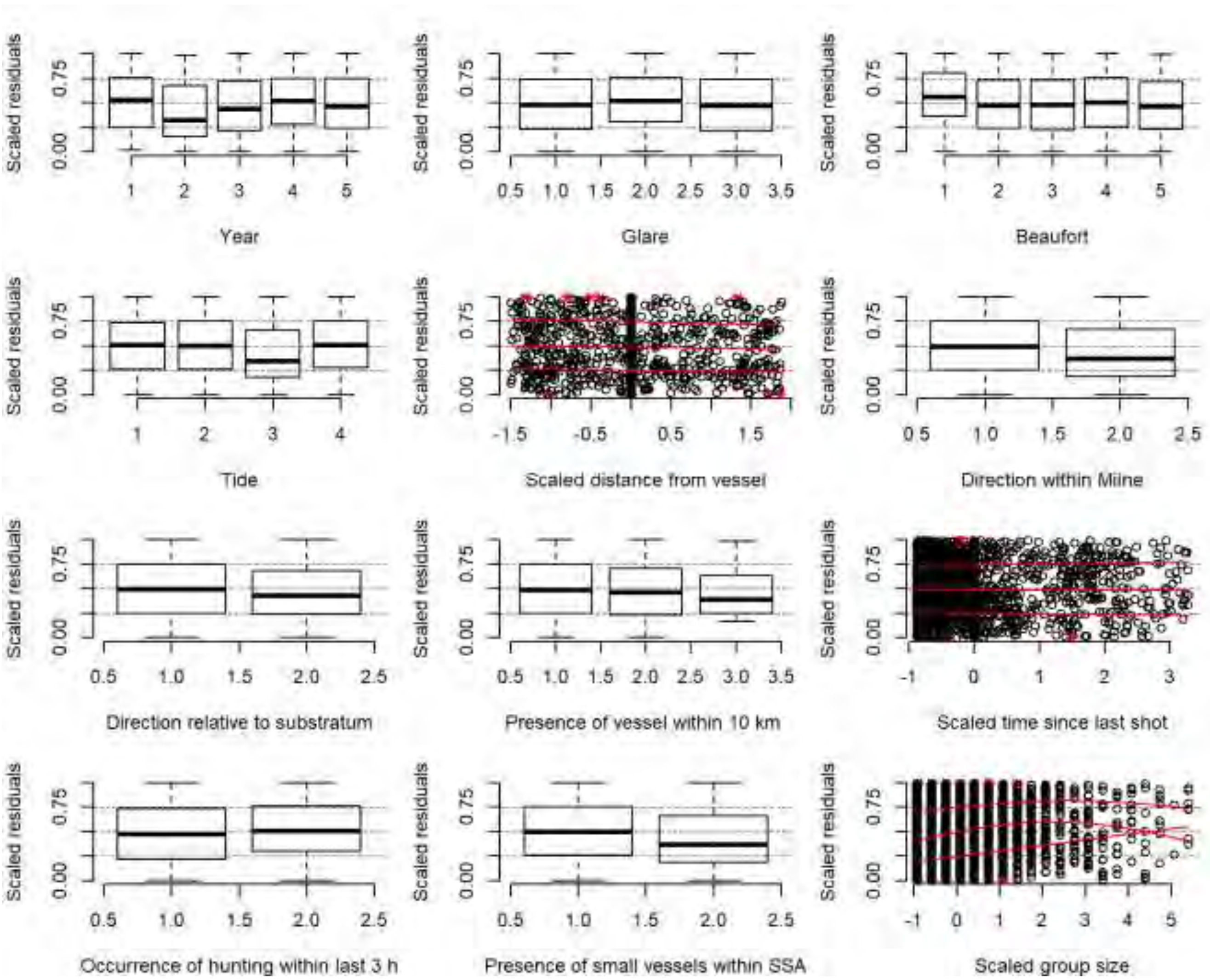


Figure D-15: Residual diagnostics for model of groups observed travelling south (rather than north) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

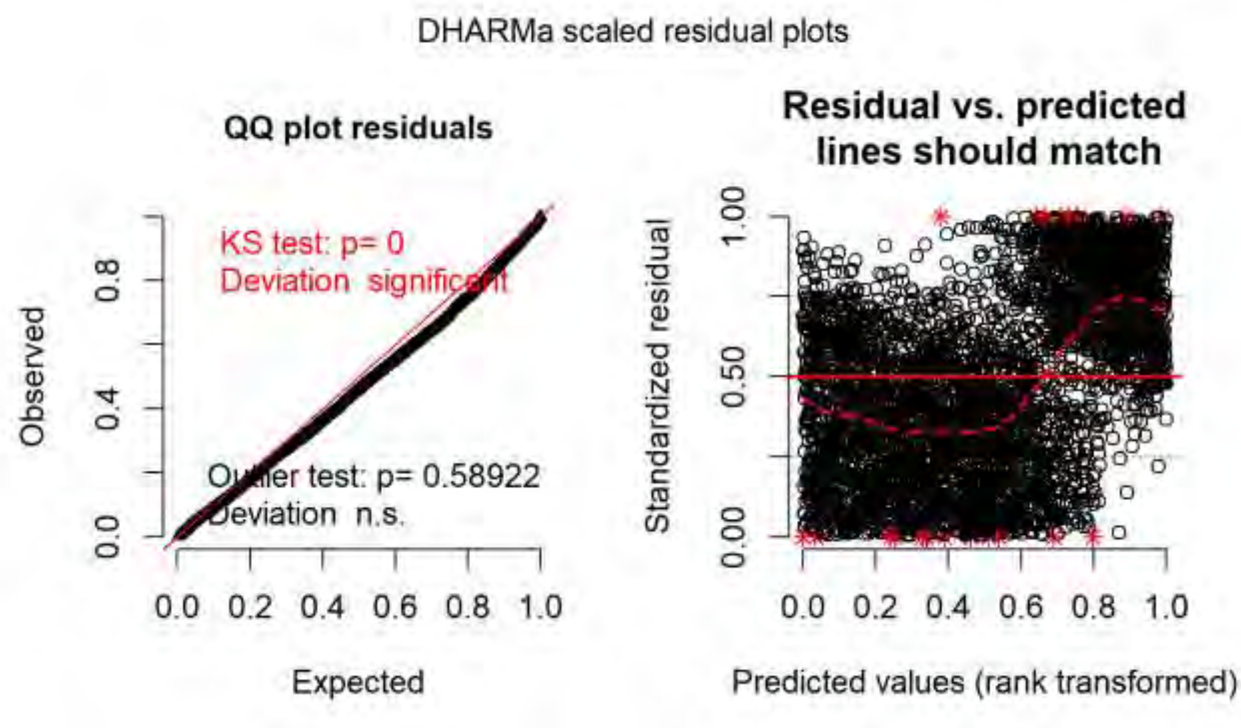


Figure D-16: Residual diagnostics for model of group travel speed (medium vs slow) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

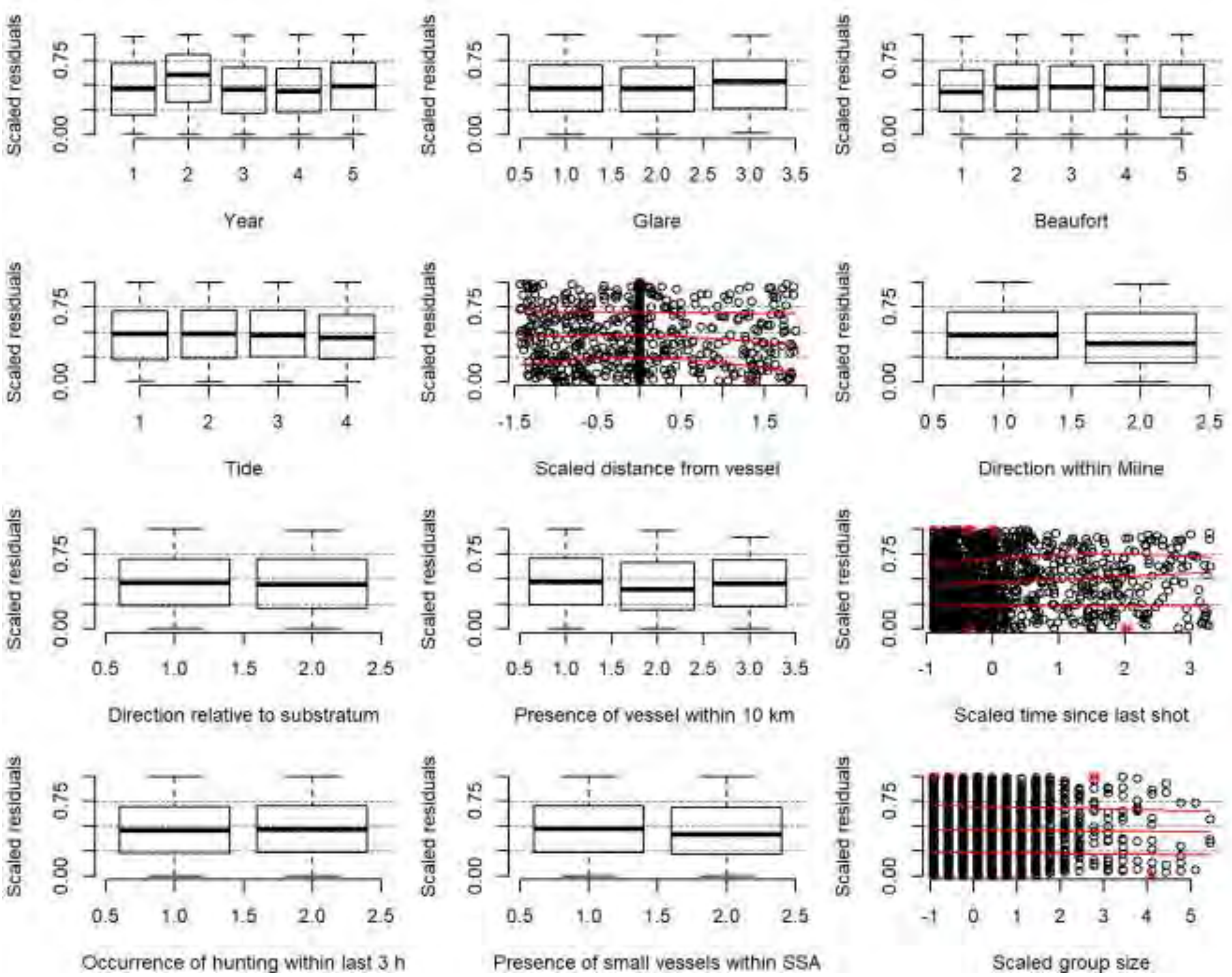


Figure D-17: Residual diagnostics for model of group travel speed (medium vs slow) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

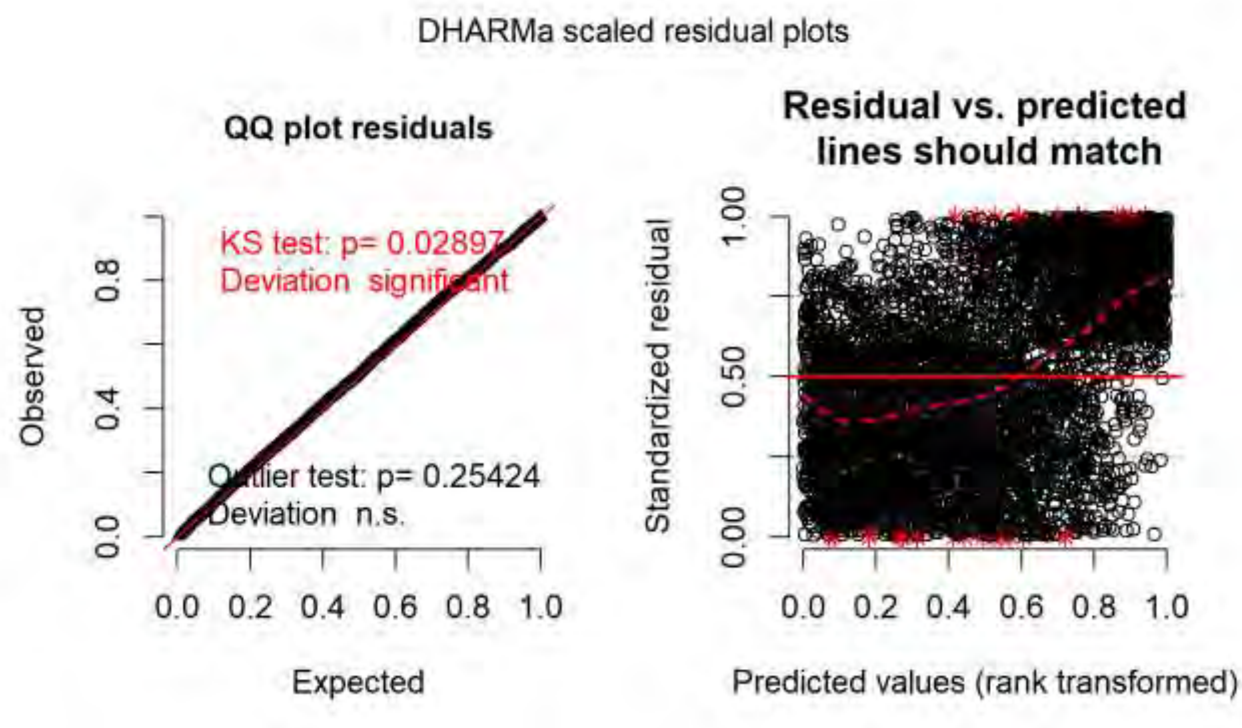


Figure D-18: Residual diagnostics for model of groups observed >300 m from shore – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

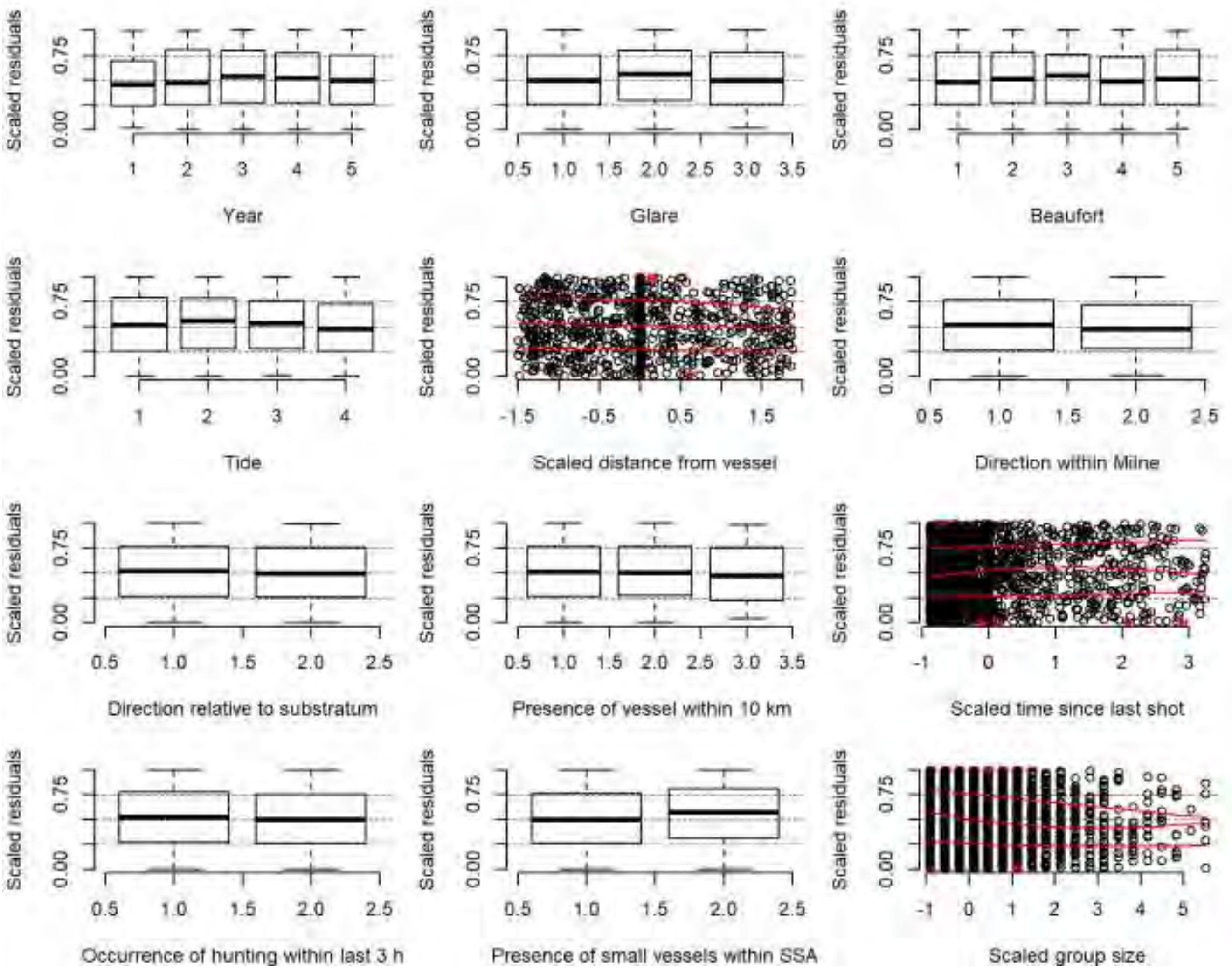


Figure D-19: Residual diagnostics for model of groups observed >300 m from shore – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

APPENDIX E

Power Analysis

POWER ANALYSIS - METHODS

A Type I error is concluding there is a significant effect when none exists (i.e., a false positive). Alpha (α) is the probability of committing a Type I error. A Type II error is the probability of concluding there is no significant effect when there is a real effect of some specified magnitude (i.e., a false negative). Beta (β) is the probability of committing a Type II error. Effect sizes are the magnitude of the change or difference in the response variables, which in this report were the metrics of diving behaviour of narwhal. The power of a statistical test (1 - β) is the probability of detecting a real effect. The power of a statistical test depends on the alpha level, the effect size, the sample size, and the variability in the data. In this analysis, the Type I error-rate (α), also referred to as the significance level, was set to 0.05. The desired minimum statistical power was 80%, which corresponds to a Type II error-rate of 0.2.

Power analyses were conducted to assess the power of statistical tests of the effect of vessel traffic on each of the analyzed response variables for relative abundance and narwhal behaviour data across a range of effect sizes, assuming the same sample size and variability as the observed data. For each model, a range of effect sizes were created. The power of detecting either an increase or a decrease in each response variable was assessed by using both negative and positive effect sizes. The results show the range of effect sizes (e.g., -50% to +50% change, depending on the response variable variable) that are required for the study to detect statistically significant effects of vessel traffic.

Data Simulation following Effect Size Application

The power to detect statistically significant effects was estimated using residual bootstrapping in R v. 3.6.1 (R 2019), following the approach of Fox and Weisberg (2018). The general approach was to simulate data based on the model selected for interpretation, the observed sample size, and the residuals, and re-run the models that were used for the original analysis using the simulated data. The data simulation and analysis were repeated 500 times for group behaviour and composition and 200 times for RAD models (due to the more intensive computing time). The proportion of repetitions where the *P*-values of interest were significant ($P<0.05$) was interpreted as the statistical power of the test.

To produce simulated data, the original model was used to predict values of the response variable. The predicted values were then adjusted according to the effect size, depending on the analysis (see below for details). The simulated data were then analyzed using the same model structure as the original analysis. Effect sizes and statistical tests were applied differently to different models and datasets, as detailed below.

Effects of a Distance from a Vessel

In the analysis of the effect of distance from a vessel (either a single vessel or the nearest vessel if multiple vessels were present within 10 km), the effect size was calculated as percent reduction or increase relative to data when no vessels were present within 10 km of the narwhal. Where effects of distance were modeled as a polynomial, the effect was only applied up to 5 km, and narwhal at >5 km from a vessel were simulated to have no effect (while still modelled as being within the exposure zone, for consistency with the original models). This distance was selected based on the results of narwhal tagging, where the majority of statistically significant results in the analyses were obtained within 5 km of a vessel. It was imposed to respect the non-linearity of the estimated effect, whereas applying the effect up to 10 km (the full exposure zone) would result in a linear simulated effect, which would not represent the observed relationship. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line (Figure 1).

The simulated data were analyzed using the same model as the original analysis described in the main report, and the *P*-values for the effects of distance on each response variable were retained, which included both the main effect of distance from vessel and any interactions with distance from a vessel. If any of these *P*-values were less than 0.05, it was considered a significant overall effect of distance from a vessel. The proportion of repetitions with at least one *P*-value less than 0.05 was interpreted as the statistical power of the overall regression for that effect size.

Effect Sizes and Data Simulation in Models with a Numeric Response Variable

For models with a numeric response variable (i.e., group size and narwhal count in the RAD dataset), the effect size was applied to the incidence rate, i.e., to the exponentiated difference in predicted values between a case where a vessel was within 5 km from narwhal and a “reference” case (where no vessel was present within 10 km from narwhal) on log-scale, rather than to the predicted values themselves. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line. For each iteration of the simulation, the predictions on the log-scale were estimated. Then, a truncated Poisson (for group size) or a negative binomial (for RAD data) distribution was used to generate a random value using the predictions calculated above. The generation of a random value was done to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels within 10 km and cases where vessels were present within 10 km, but farther than 5 km from the narwhal), predictions were still used to generate a random value, resulting in simulated data that differed from the originally collected data.

To produce simulated data for these models, the original dataset was duplicated, and in the duplicate dataset, all data were treated as reference (i.e., no vessels within 10 km from narwhal). The original model was used to predict response values for this duplicate dataset, creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied to the predicted “reference” values. For all data cases that were “impact” cases in the original data, the predicted “reference” response was multiplied by the effect size, to produce a range of responses as the various effect sizes. For Poisson and negative binomial models, the effect size was applied to the incidence rates – that is, the exponentiated difference between the log-scale predictions of “reference” and “impact” cases.

The simulated data were then analyzed using the same model structure as the original analysis.

Effect Sizes and Data Simulation in Logistic Models

For models with a binary response variable (e.g., presence/absence of tusks or calves), the effect size was applied to the odds ratio, i.e., to the exponentiated difference in predicted values between a case where a vessel was within 5 km from narwhal and a “reference” case (where no vessel was present within 10 km from narwhal) on logit-scale, rather than to the predicted values themselves. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line. However, due to the nonlinearity of probabilities, a negative and a positive effect size of the same magnitude may result in asymmetrical magnitudes of change on the probability scale (Figure 2). For each iteration of the simulation, the predictions on the logit scale were used to calculate the probability of the outcome. Then, a binomial distribution was used to generate a random value using the probability of the outcome calculated above. The generation of a random probability was done to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels within 10 km and cases where vessels were present within 10 km, but farther than 5 km from the narwhal), predictions were still used to generate a random value, resulting in simulated data that differed from the originally collected data.

To produce simulated data for logistic models, the original dataset was duplicated, and in the duplicate dataset, all data were treated as reference (i.e., no vessels within 10 km from narwhal). The original model was used to predict response values for this duplicate dataset, creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied to the predicted “reference” values. For all data cases that were “impact” cases in the original data, the predicted “reference” response was multiplied by the effect size, to produce a range of responses as the various effect sizes. For logistic models, the effect size was applied to the odds ratio – that is, the exponentiated difference between the logit-scale predictions of “reference” and “impact” cases.

Effect Sizes and Data Simulation in Linear Models

For models with a linear relationship between distance from vessel and the response variable, the effect size was applied to the full 10 km distance from vessel, so that the simulation did not create a nonlinearity in the effect. Multiple comparisons were performed as detailed above, comparing the effects of vessels at various distances from narwhal to cases when no vessels were presence.

Effects of Multiple Vessels

In addition to the effect of distance from the nearest vessel, the analyses presented in the main report also incorporated the effects of presence of multiple vessels, where the question of interest was whether the effect of presence of multiple vessels within 10 km from narwhal was different from the effect of presence of a single vessel. To assess the statistical power of the models to detect this effect, the effect size was calculated as percent reduction or increase relative to data when only a single vessel was present within 10 km from narwhal, and relative to when no vessels were present within 10 km.

For analyses of multiple vessel effects, the *P*-values associated with the effect of multiple vessel presence were retained. For each effect size, the data simulation and analysis were repeated 500 times for group behaviour and composition and 200 times for RAD models (due to the more intensive computing time). The proportion of repetitions with $P<0.05$ for the effects of models was interpreted as the power to detect an overall effect of number of vessels.

Effect Sizes and Data Simulation in Models with a Numeric Response Variable

To produce simulated data, the original dataset was duplicated, and in the duplicate dataset, all data where any vessels were present were treated as reference (i.e., only a single vessel within 10 km from substratum or BSA). The original model was used to predict response values for this duplicate dataset (on link or transformed scale, as applicable), creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied – for all data cases that were “impact” cases in the original data (i.e., had multiple vessels present within 10 km), the predicted “reference” response (on the transformed scale) was multiplied by the effect size, to produce a range of response values at the different effect sizes.

For each iteration of the simulation, the predicted response was used to draw at random from either a truncated Poisson distribution (for group size model) or from a negative binomial distribution (for the RAD model), to produce a set of simulated data. These random draws were performed to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels or only a single vessel), predictions were still used to draw random values from the respective distribution, to generate a simulated dataset that differed from the originally collected data.

Effect Sizes and Data Simulation in Logistic Models

To produce simulated data, the original dataset was duplicated, and in the duplicate dataset, all data were treated as reference (i.e., only a single vessel within 10 km from the BSA). The original model was used to predict response values for this duplicate dataset on the logit scale, creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied to the “reference” dataset. For logistic models, the effect size was applied to the odds ratio – that is, the exponentiated difference between the logit-scale predictions of “reference” and “impact” cases. After the application of effect sizes, the predicted values were used to calculate the probability of the outcome (e.g., the probability of a narwhal with a tusk being present in a group) for each case in the dataset. Then, a binomial distribution was used to generate a random value using the probability of the outcome calculated above. The generation of a random value was done to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels or only a single vessel), predictions were still used to generate a random value, resulting in simulated data that differed from the originally collected data.

Power Analysis – Reporting of Results

To summarize the results of the power analyses, power curves were produced. Power curves show statistical power, which is the probability of detecting a significant effect, as a function of effect size, which is shown as a percentage change of the response variable. Separate curves were produced for overall effects and for multiple comparisons (for effects of distance only). Horizontal lines were added to visualize statistical power values of 0.8 (hereafter sufficient power) and 0.9 (hereafter high power). A vertical line was added to visualize the magnitude of difference that was observed in the original data.

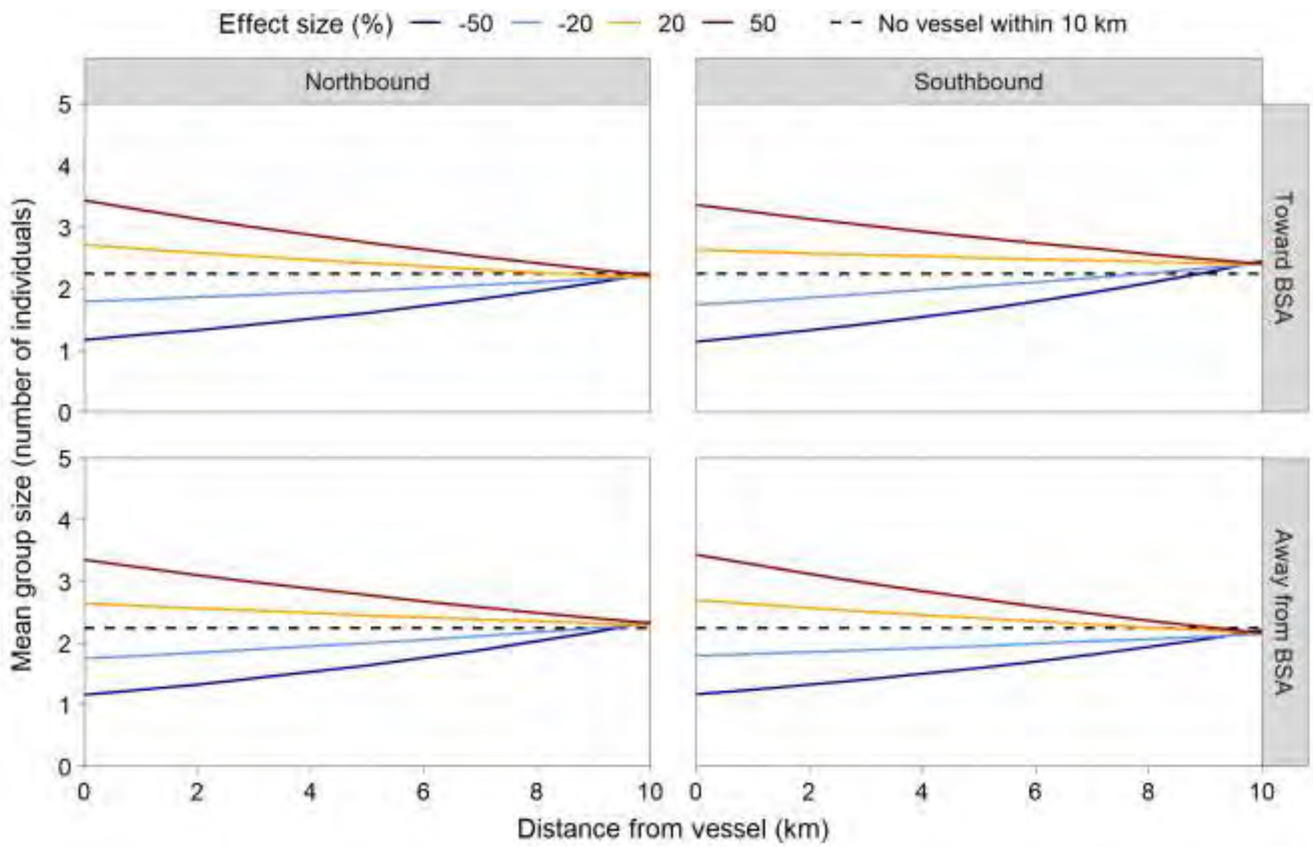


Figure 1: Application of effect sizes to a model with a numeric response variable (group size).

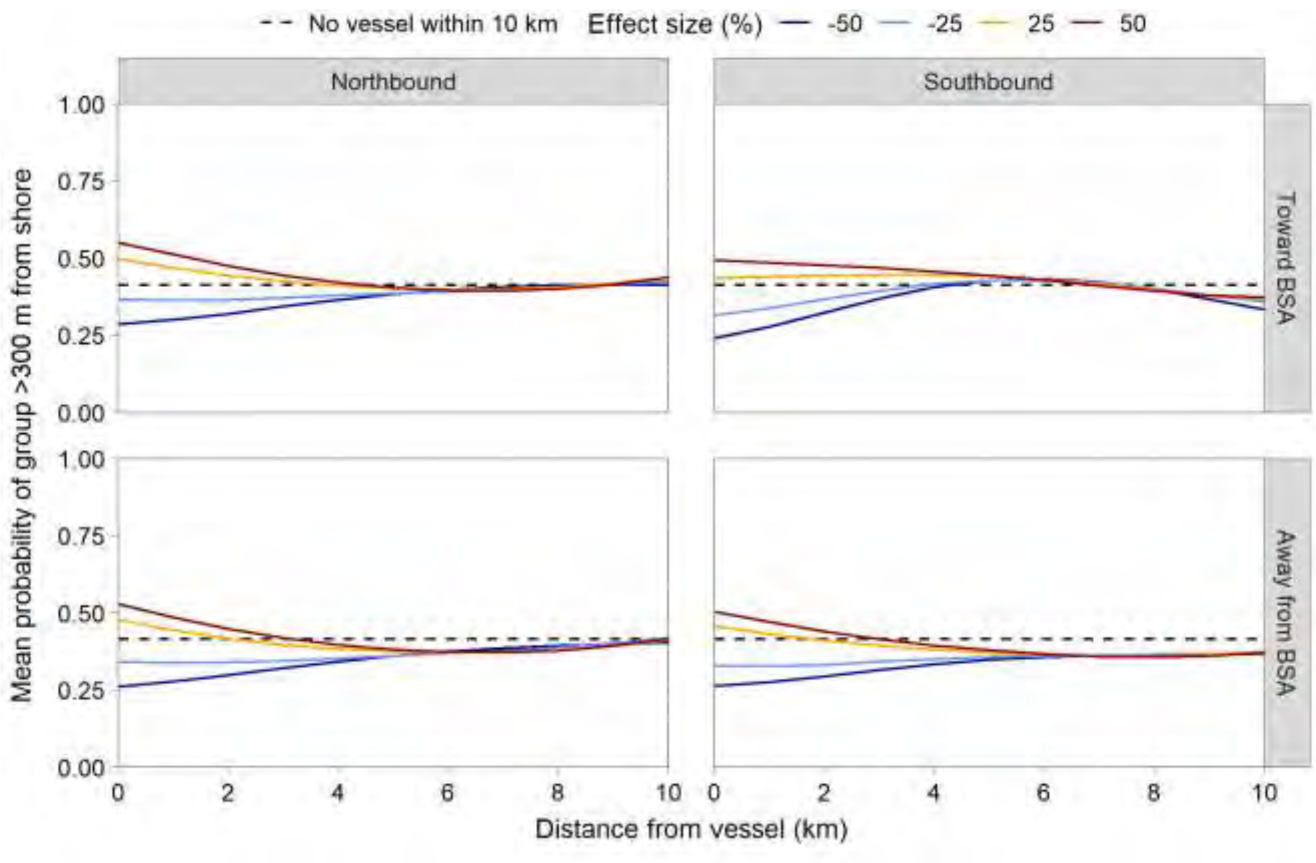


Figure 2: Application of effect sizes to a model with a binary response variable (group distance from shore)

POWER ANALYSIS – RESULTS

RAD

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on relative abundance at effect sizes of approximately -65% or +85% (Figure 5). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -55% (for a southbound vessel moving toward the substratum) to +82% (for a southbound vessel moving away from the substratum). Statistical power to estimate the observed effects ranged between approximately 0.3 (for northbound vessels heading toward substratum) to approximately 0.8 (for southbound vessels, moving away from substratum). That is, the analysis had sufficient power to detect effect sizes of -65% or +85%, and the original analysis found a significant effect of vessel distance on relative abundance, despite effect sizes at 0 km being less than those required for power of 0.8.

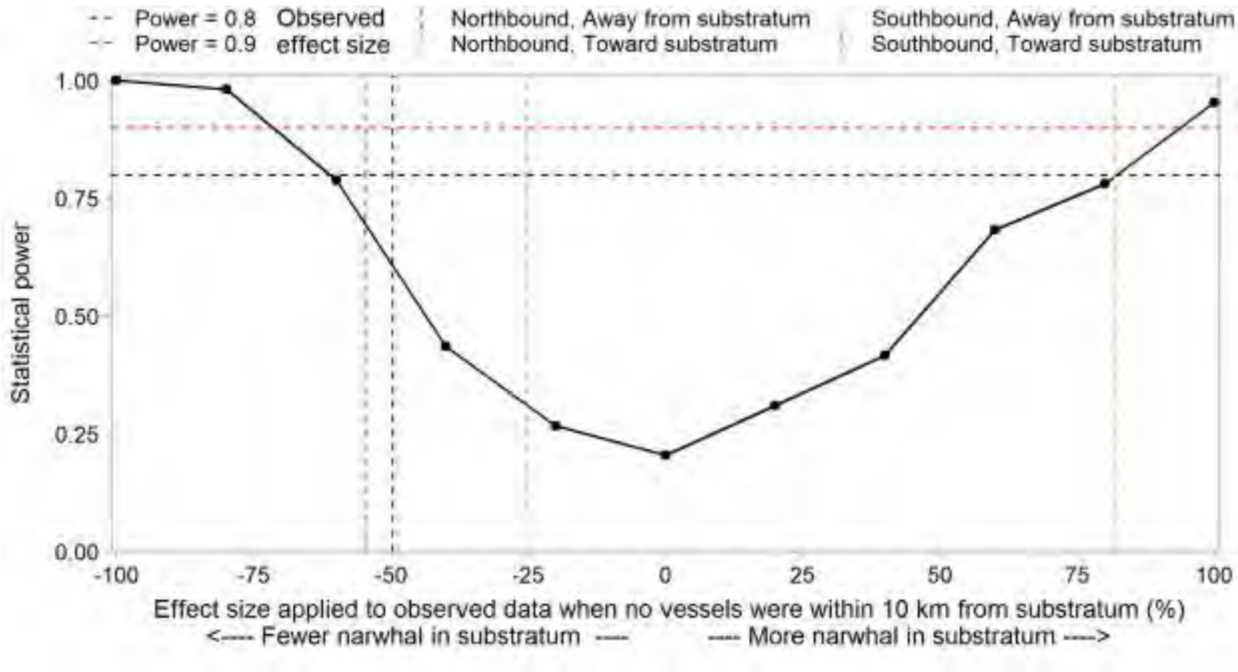


Figure 3: Statistical power of the overall model of RAD to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to substratum centroids.

Effects of Multiple Vessel Present within 10 km from Centroid

There was sufficient power to detect an overall effect of number of vessels on relative abundance at effect sizes of approximately -70% or +100% (Figure 4). Observed effect size was +27% (difference between 2+ vessels and a single vessel), however the original analysis did find a significant effect of the number of vessels present within 10 km from the substratum (*P*=0.011) despite the low power at this effect size (approximately 0.38).

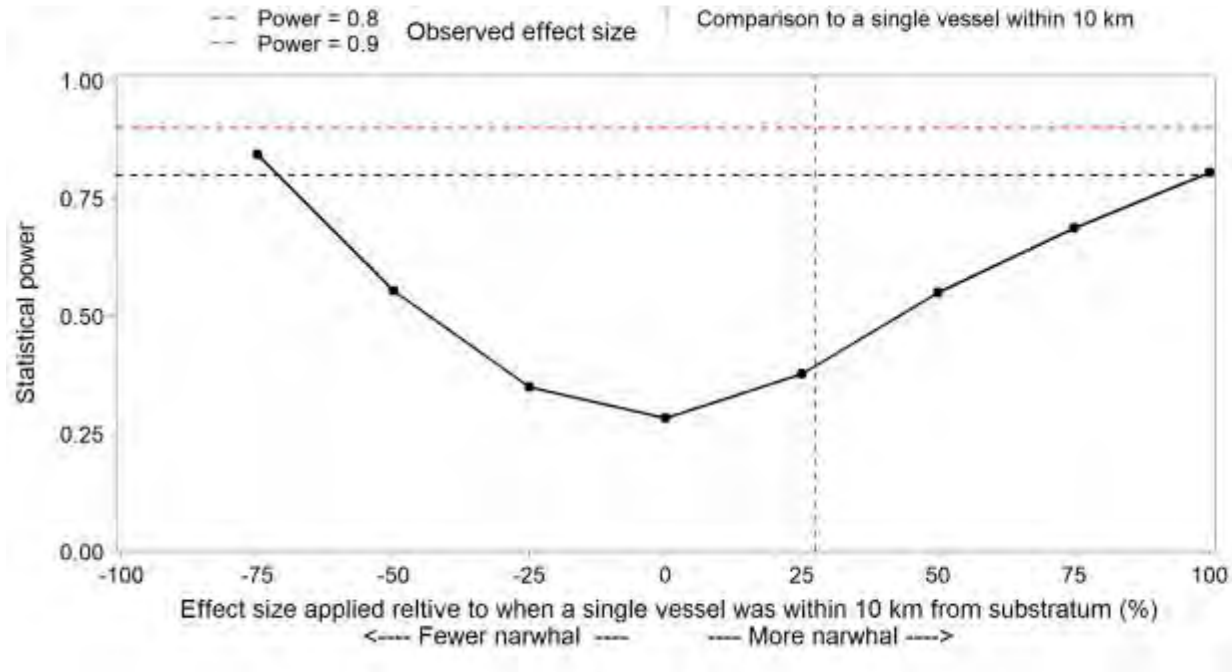


Figure 4: Statistical power of the overall model of relative abundance to detect a significant effect of number of vessels within 10 km from substratum centroid, showing observed effect sizes at 2+ vessels relative to a single vessel.

Group size

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group size at effect sizes of approximately -35% or +45% (Figure 5). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -11% (for a northbound vessel moving toward the BSA) to +27% (for a northbound vessel moving away from the BSA). Statistical power to estimate the observed effects was <0.5. That is, the analysis had sufficient power to detect effect sizes of -35% or +45%, however the absolute magnitude of observed effect sizes was smaller than that, and the original analysis did not find a significant effect of vessel distance on group size.

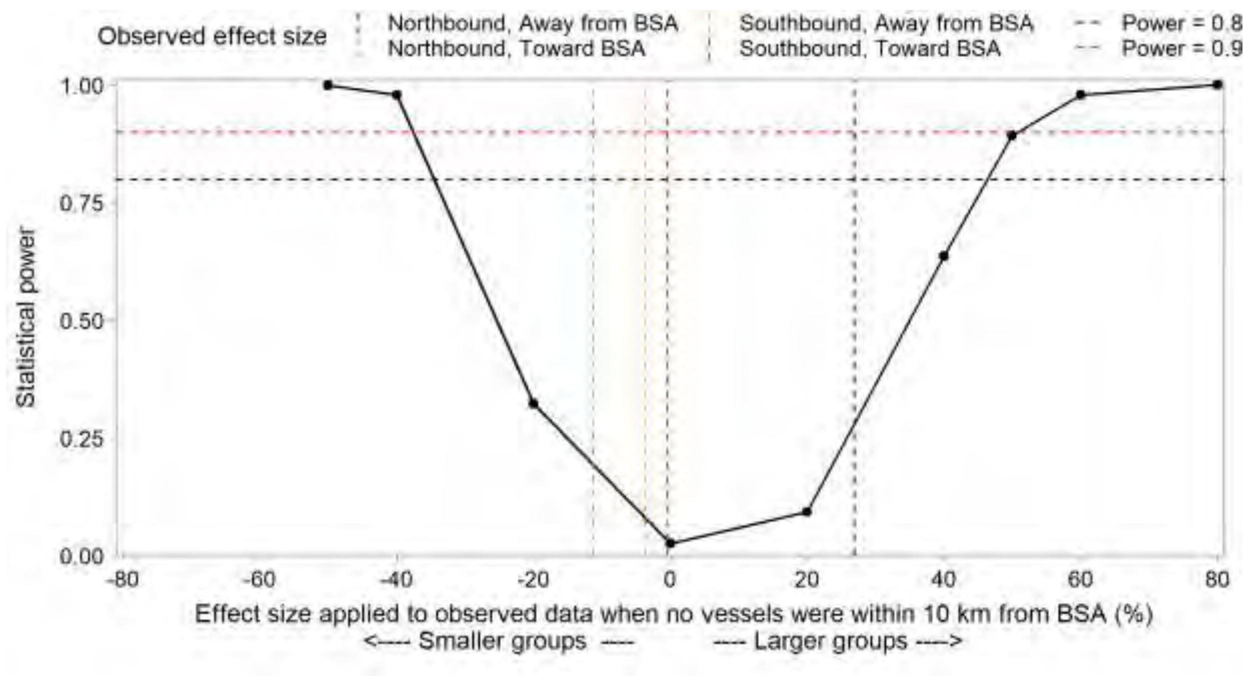


Figure 5: Statistical power of the overall model of group size to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was sufficient power (>0.8) to detect an overall effect of number of vessels on group size at effect sizes of approximately -55% or +92% (Figure 6). In comparison, the observed effect size was 32% (difference between a single vessel and 2+ vessels). Statistical power to estimate the observed effect was <0.1. That is, the magnitude of observed effect size was not sufficient to detect an overall effect of number of vessels, but power would be sufficient to detect effect sizes of -55% or +92%.

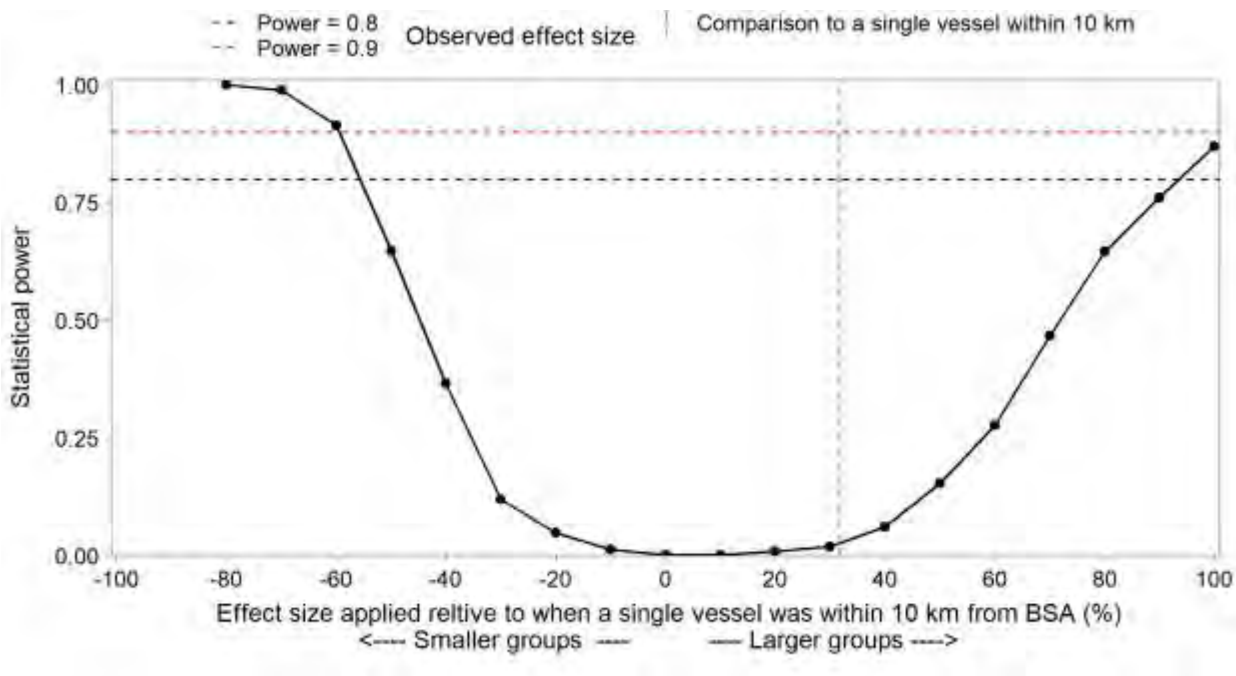


Figure 6: Statistical power of the overall model of group size to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Group Composition – Presence of Calves or Yearlings

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on presence of calves or yearlings within observed groups at effect sizes of approximately -70% or +100% (Figure 7). In comparison, observed effect sizes ranged from –4% (for a southbound vessel moving toward the BSA) to +6,694% (for a northbound vessel moving toward the BSA). Statistical power to estimate the observed effects was >0.95 for most effects, except for the effect of a southbound vessel heading toward the BSA, where statistical power was approximately 0.35. Since most observed effect sizes were well above the effect size required to achieve sufficient statistical power, the original analysis found a significant effect of vessel distance (Section 5.4.2.2 in main report).

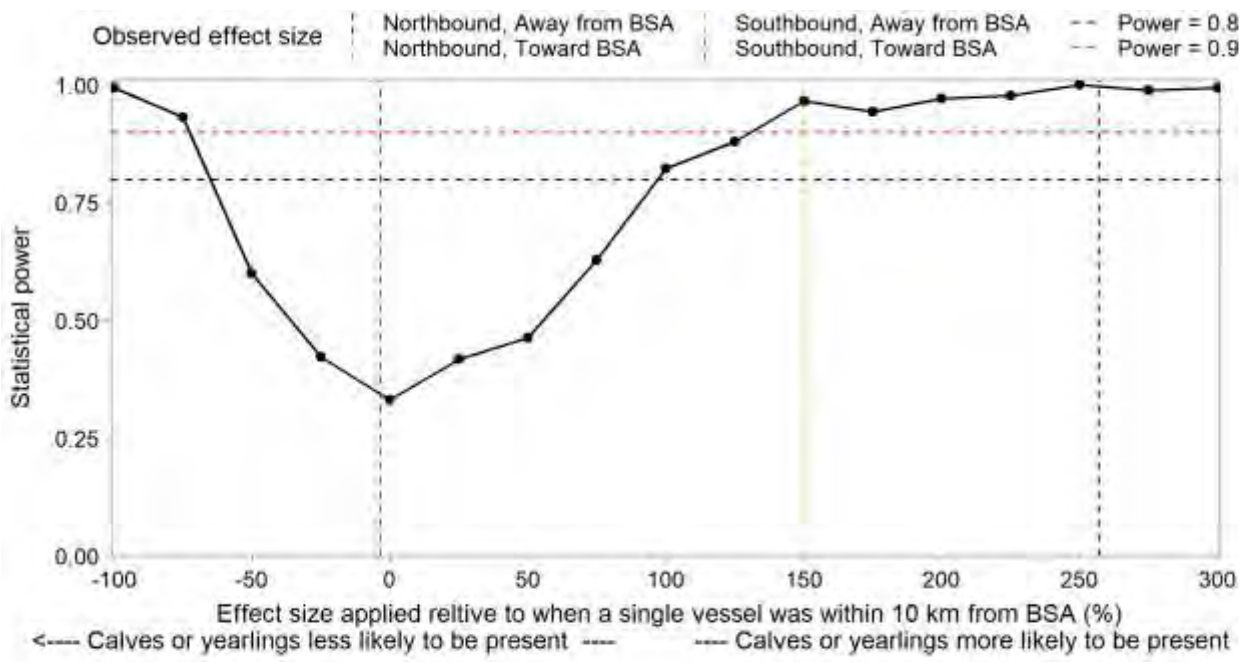


Figure 7: Statistical power of the overall model of presence of calves or yearlings to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Note: Observed effect size for northbound vessels heading toward BSA (6,694%) not shown on figure.

Effects of Multiple Vessel Present within 10 km from BSA

There was sufficient power (>0.8) to detect an overall effect of number of vessels on the presence of calves or yearlings at effect sizes of -50% or +210% (**Error! Reference source not found.**). Observed effect size was 11% (difference between 2+ vessels a single vessel), and the original analysis did not find an overall significant effect of number of vessels present within 10 km from the BSA (*P*=0.132).

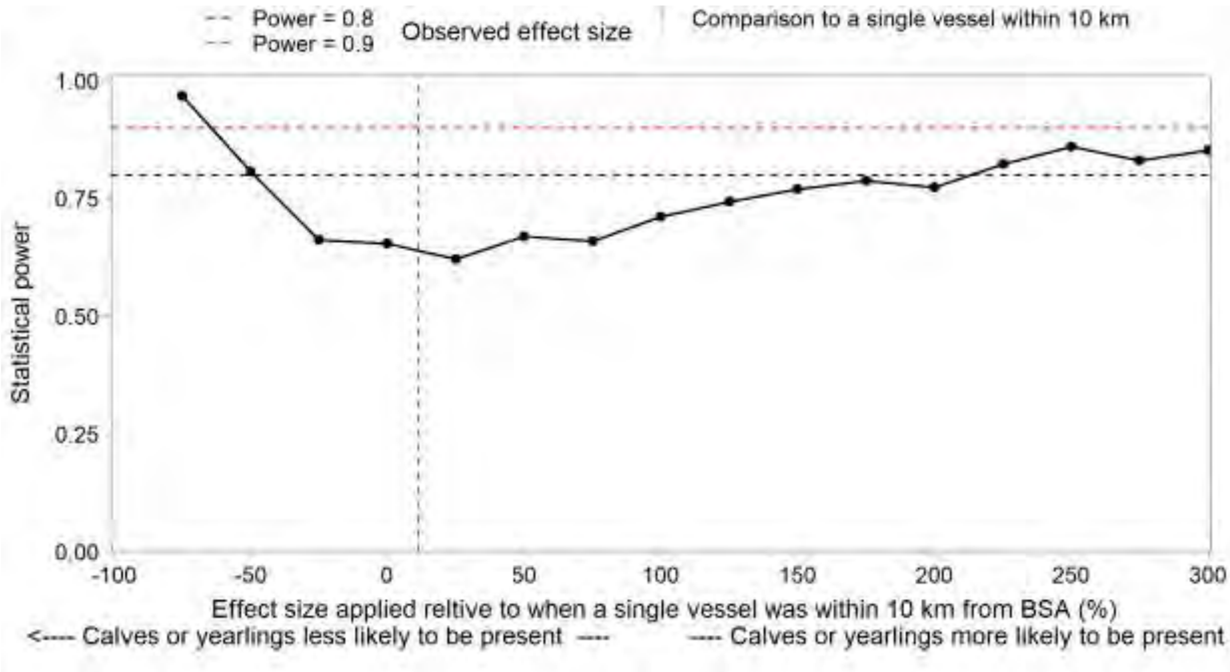


Figure 8: Statistical power of the overall model of presence of calves or yearlings to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Group Spread

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group spread at effect sizes of approximately -80% or +170% (Figure 9). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -93% (for a northbound vessel moving toward from the BSA) to +11% (for a southbound vessel moving away from the BSA). Statistical power to estimate the observed effects was less than 0.25 for most effects at a distance of 0 km from a vessel, except for the effect of a northbound vessel heading toward the BSA, where statistical power was >0.9. Since most observed effect sizes were below the effect size required to achieve sufficient statistical power, the original analysis did not find a significant effect of vessel distance (Section 5.4.3 in main report).

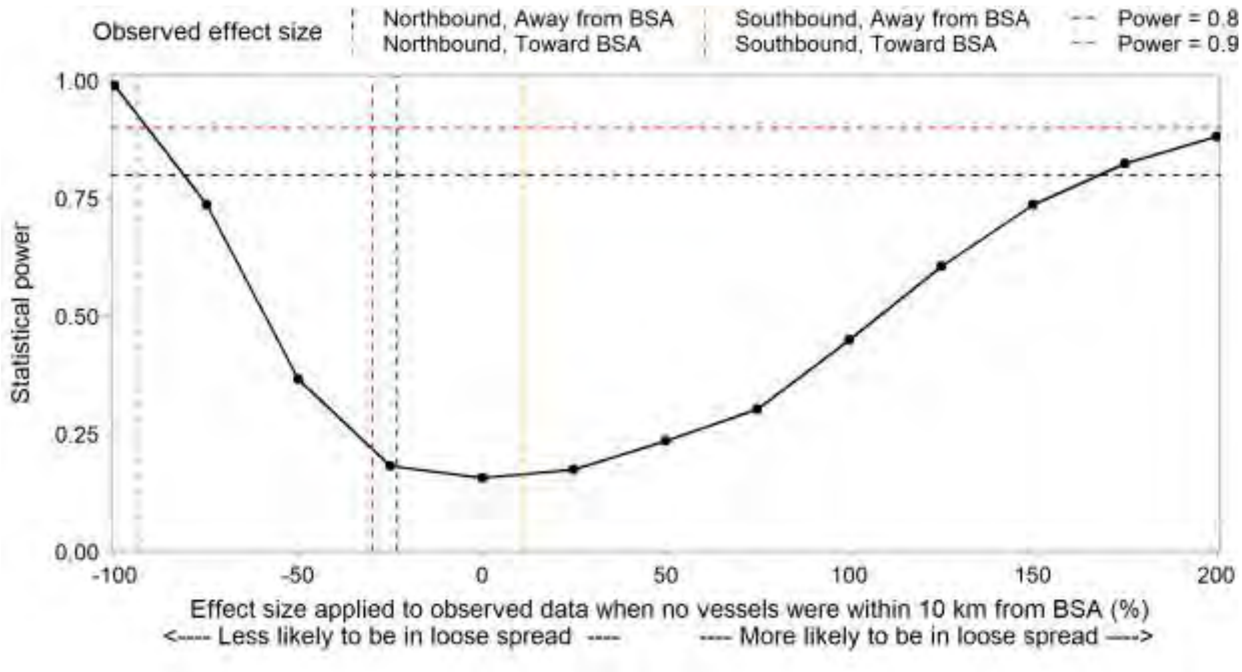


Figure 9: Statistical power of the overall model of group spread to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was sufficient power (>0.8) to detect an overall effect of number of vessels on group spread at effect sizes of approximately +250% (Figure 10). Observed effect size was 108% (difference between 2+ vessels and a single vessel), and the original analysis did not find a significant effect of the number of vessels present within 10 km from the BSA (*P*=0.093).

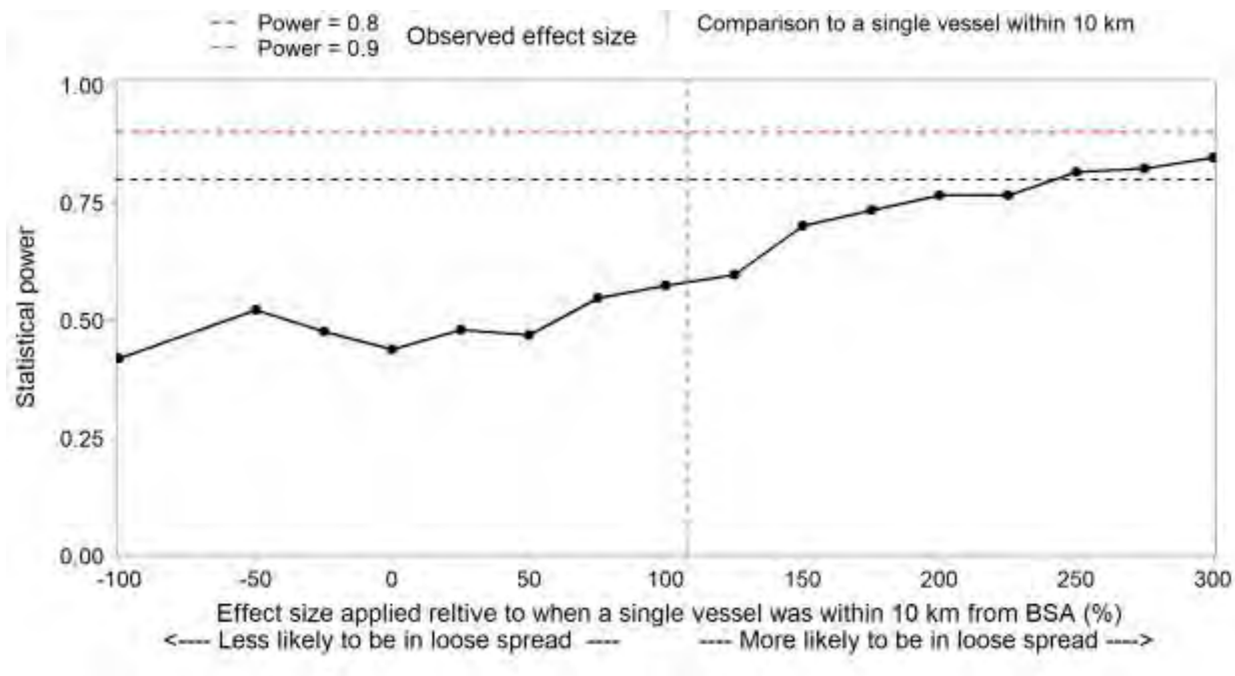


Figure 10: Statistical power of the overall model of group spread to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Group Formation

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group formation at effect sizes of approximately -90% or +160% (Figure 11). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -87% (for a northbound vessel moving toward the BSA) to -58% (for a northbound vessel moving away from the BSA). Statistical power to estimate the observed effects was approximately 0.8 for a northbound vessel moving toward the BSA, but only 0.3-0.5 for the other three scenarios. Since most of the observed effect sizes were below the effect size required to achieve sufficient statistical power, the original analysis did not find a significant effect of vessel distance despite noting a possible effect due to relatively large effect sizes (Section 5.4.4 in main report).

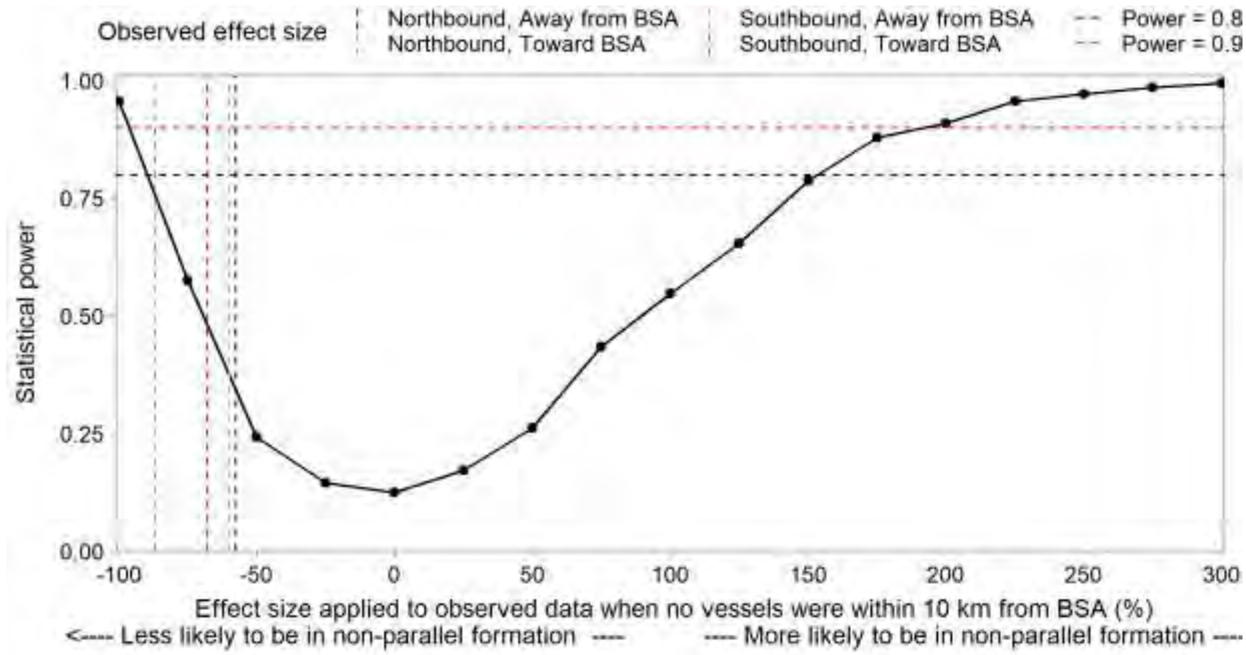


Figure 11: Statistical power of the overall model of group formation to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was not sufficient power (>0.8) to detect an overall effect of number of vessels on group formation at any of the examined effect sizes , ranging between -100% and +300% (Figure 12). Observed effect size was only -2% (difference between 2+ vessels and a single vessel), and the original analysis did not find a significant effect of the number of vessels present within 10 km from the BSA (*P*=0.723).

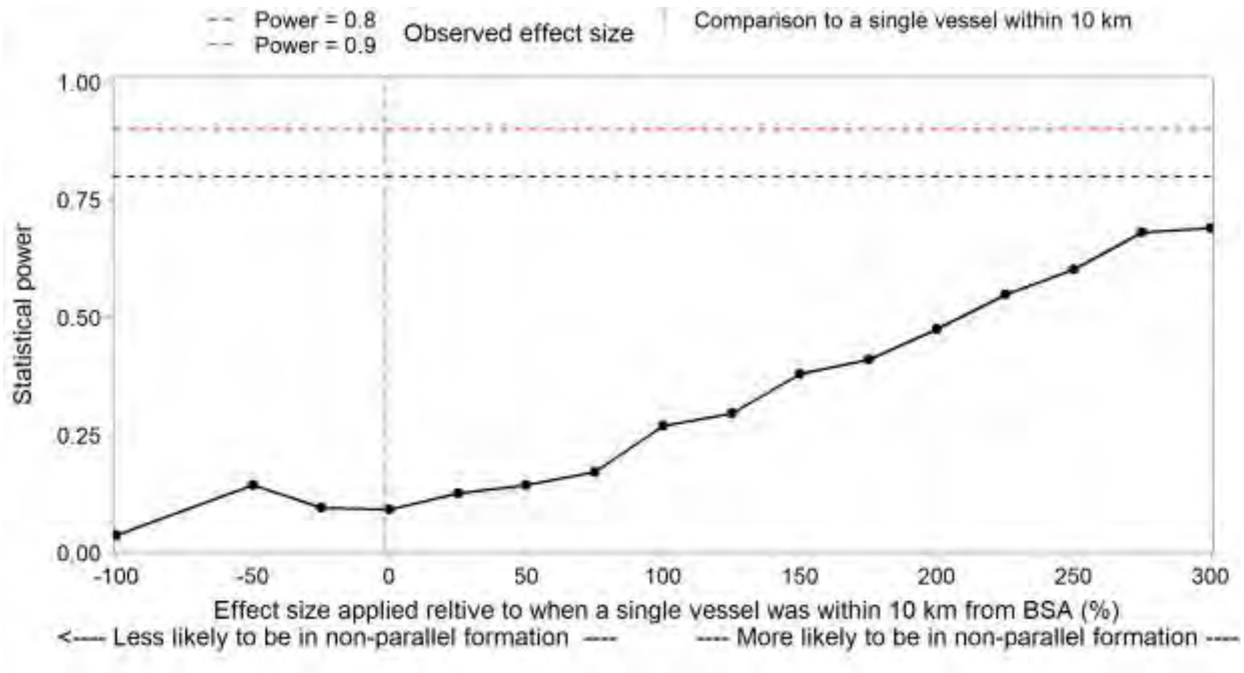


Figure 12: Statistical power of the overall model of group formation to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Group Direction

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group direction at an effect size of approximately -95%, whereas all of the assessed positive effect sizes had insufficient power (Figure 13). Observed effect sizes at a distance of 0 km from vessels ranged from +1,891% (for a southbound vessel moving away from the BSA) to +3,171% (for a northbound vessel moving away from the BSA). Statistical power to estimate the observed effects was approximately 0.2-0.35 for all of the observed effect sizes at a distance of 0 km. Despite the low power at positive effect sizes, the original analysis found a significant effect of vessel distance (Section 5.4.5 in main report).

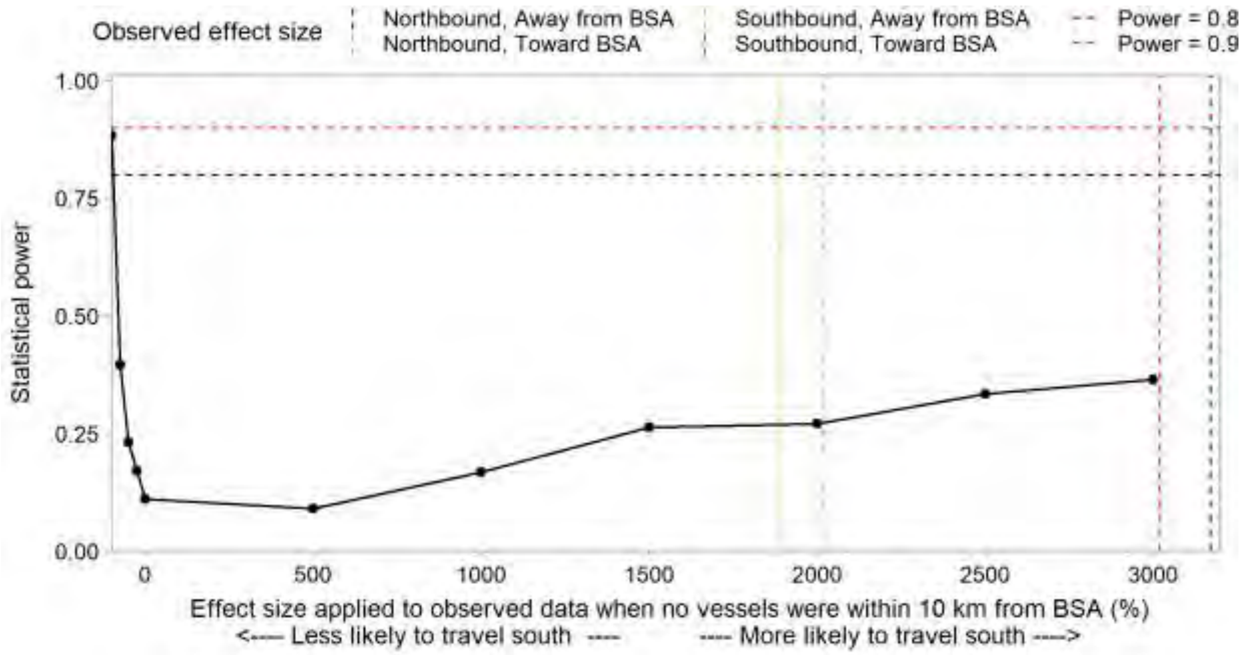


Figure 13: Statistical power of the overall model of group direction to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was not sufficient power (>0.8) to detect an overall effect of number of vessels on group direction at any of the examined effect sizes , ranging between -100% and +300% (Figure 14). Observed effect size was +287% (difference between 2+ vessels and a single vessel), and the original analysis did not find a significant effect of the number of vessels present within 10 km from the BSA (*P*=0.0.715).

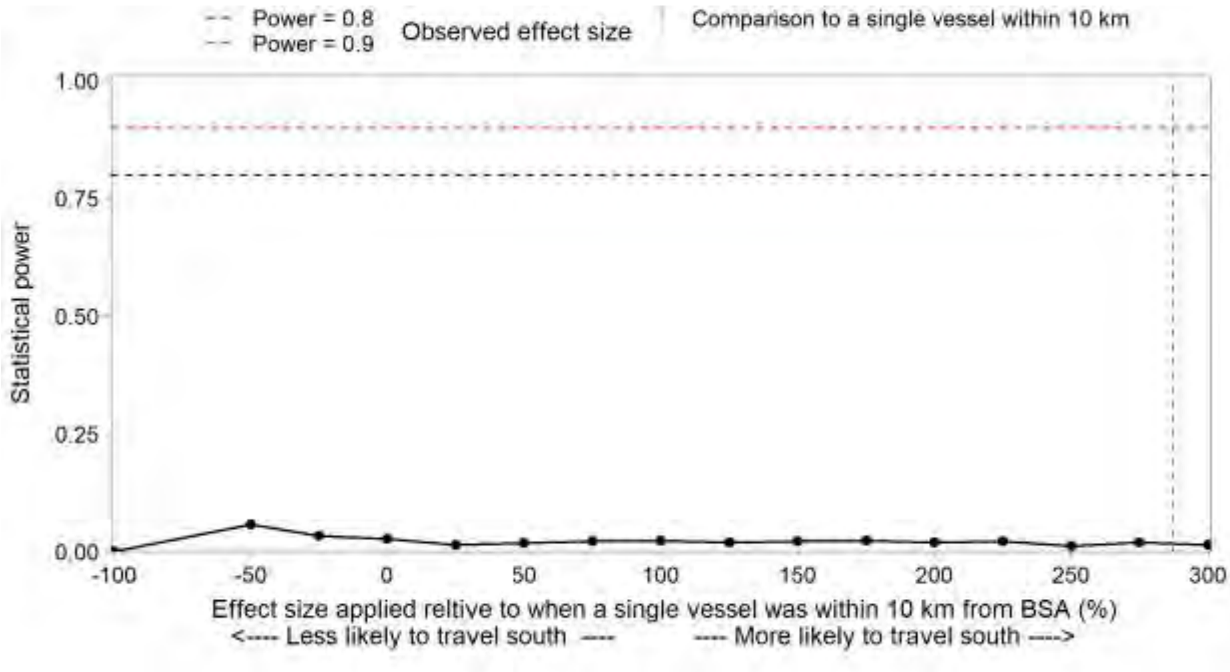


Figure 14: Statistical power of the overall model of group direction to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Travel Speed

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group travel speed at effect sizes of approximately -90% or +200% (Figure 15). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -76% (for a southbound vessel moving toward the BSA) to -11% (for a northbound vessel moving toward the BSA). Statistical power to estimate the observed effects was less than 0.3 for all observed effect sizes at a distance of 0 km from vessels. The original analysis did not find a significant effect of vessel distance on group travel speed (Section 5.4.6.1 in main report).

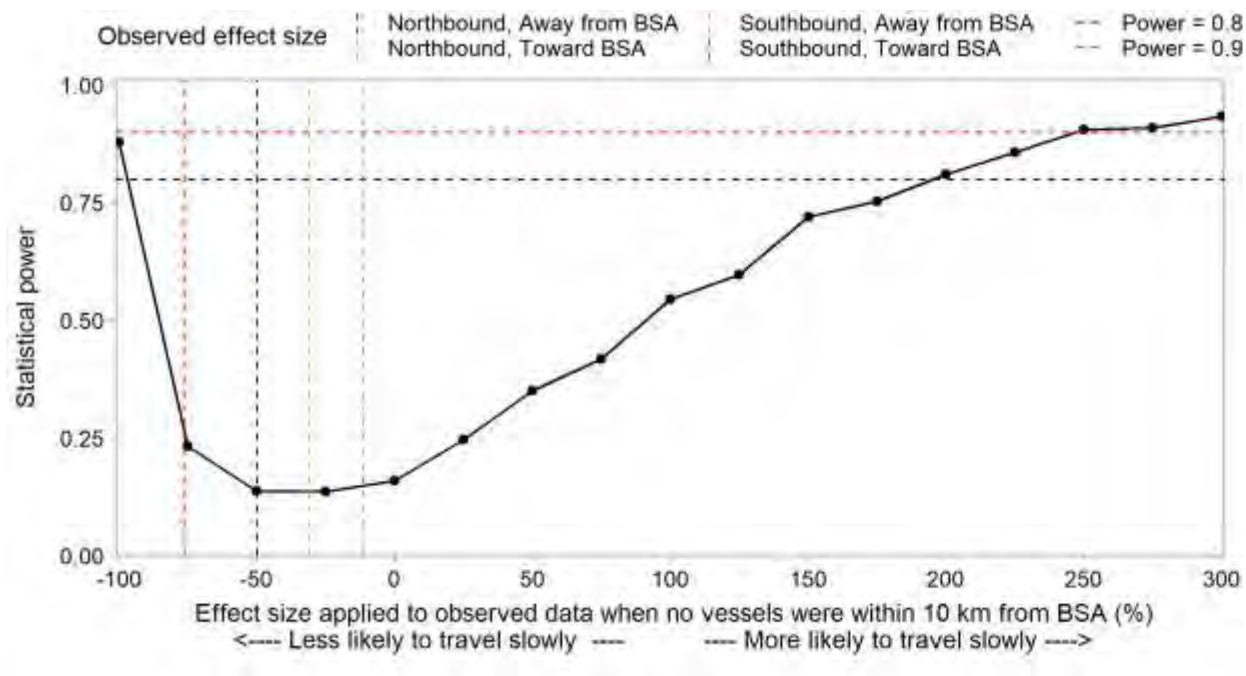


Figure 15: Statistical power of the overall model of group travel speed to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was not sufficient power to detect an overall effect of number of vessels on group travel speeds at any of the examined effect sizes, ranging between -100% and +300% (Figure 16). Observed effect size was only -4% (difference between 2+ vessels and a single vessel), and the original analysis did not find a significant effect of the number of vessels present within 10 km from the BSA (*P*=0.884).

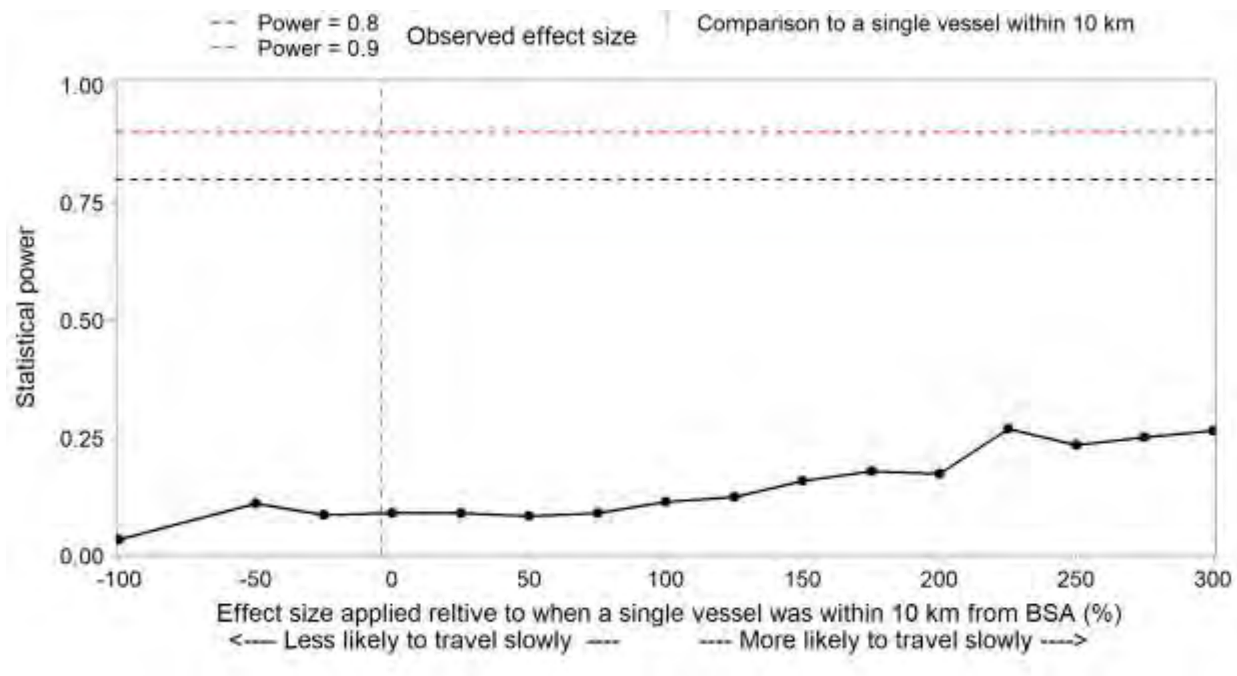


Figure 16: Statistical power of the overall model of group travel speed to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Distance from Bruce Head Shore

Effects of Distance from a Single Vessel

There was sufficient power (>0.8) to detect an effect of distance from vessel on group distance from shore at effect sizes of approximately -90% or +200% (Figure 17). In comparison, observed effect sizes at a distance of 0 km from vessels ranged from -98% (for a southbound vessel moving toward the BSA) to -34% (for a southbound vessel moving away from the BSA). Statistical power to estimate the observed effects was less than 0.4 for vessels moving away from the BSA and 0.8-0.9 for vessels moving toward the BSA. With half of the observed effect sizes at 0 km from vessels having power of >0.8, the original analysis did find a significant effect of vessel distance on group distance from shore (Section 5.4.7 in main report).

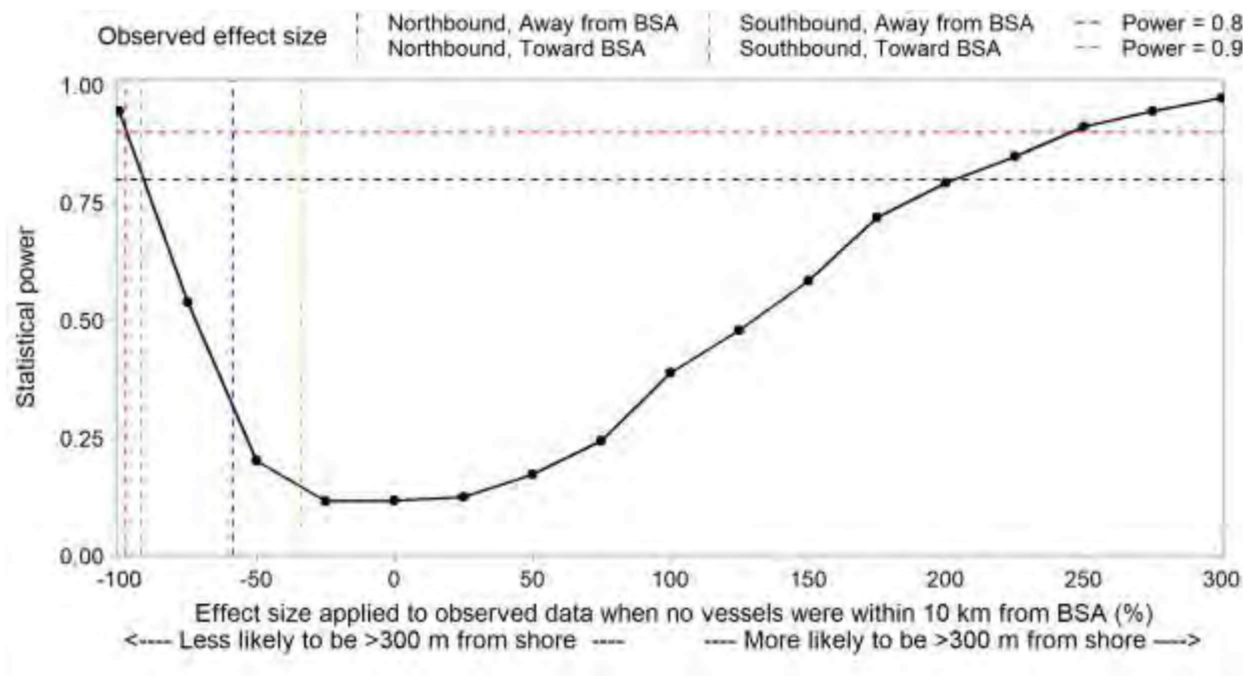


Figure 17: Statistical power of the overall model of group distance from shore to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Effects of Multiple Vessel Present within 10 km from BSA

There was sufficient power (>0.8) to detect an overall effect of number of vessels on group distance from shore at effect sizes of approximately +50% or higher (Figure 18). Observed effect size was -89% (difference between 2+ vessels and a single vessel), and the original analysis did not find a significant effect of the number of vessels present within 10 km from the BSA (*P*=0.12).

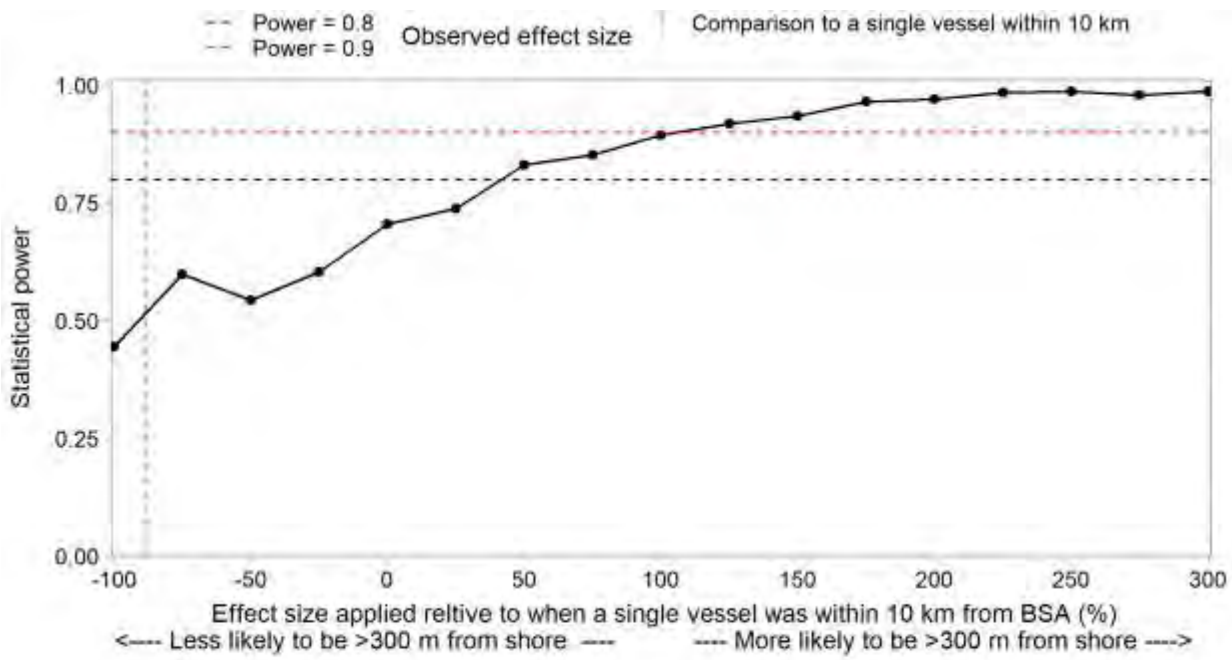


Figure 18: Statistical power of the overall model of group distance from shore to detect a significant effect of number of vessels within 10 km from BSA, showing observed effect sizes at 2+ vessels relative to a single vessel.

Summary

Effects of Distance from a Single Vessel

Most of the assessed analyses required large effect sizes for sufficient (>0.8) statistical power to detect an effect of distance from vessels (reductions of 70-90% or increases of 100-200% in the odds or in the incidence rates; Table 1). The one exception was group size, where a reduction of 25% or an increase of 45% in the incidence rates were required to obtain sufficient statistical power to detect an effect of distance from vessels.

This result is likely a combination of several factors:

- Inherent data variability
- Sparse data in the immediate vicinity of vessels (only 150 and 28 cases in behavioural data when vessels were within 2 km and within 1 km from the BSA centroid, respectively)
- Smaller dataset for group composition and behaviour data (5,025 cases, compared to 32,466 for RAD data), which reduces the statistical power of tests performed on group behaviour and composition data relative to the RAD data
- The spatial extent included in the “exposure to vessels” (10 km) may be too large, based on results of narwhal tagging (Golder 2020a). This would result in an increase in variability and a reduction in the ability to detect vessel effects, especially at shorter distances from vessels.

In the original analyses, the RAD analysis and three of the eight group composition and behaviour analyses detected an overall effect of distance from vessel. Overall, the results of the power analysis presented here indicate that group composition analyses generally had low power, therefore the effect of distance from vessel should be assessed using effect sizes rather than a strict adherence to statistical significance. As additional data are collected, and especially if the spatial extent of exposure to vessels is reduced further from the current 10 km limit, it is expected that statistical power would increase.

Effects of Multiple Vessel Present within 10 km from BSA

Most of the assessed analyses required large effect sizes for sufficient (>0.8) statistical power to detect an effect of distance from vessels (generally, reductions of 50% or increases of 90-200% in the odds or in the incidence rates; Table 2). In three of the analyses (group formation, direction, and speed), none of the examined effect sizes (ranging between -100% and +300%) resulted in sufficient power. In two other analyses (group spread, and distance from shore), only increases in odds resulted in sufficient statistical power. In the original analyses, only the analysis of RAD data resulted in a significant effect of the overall number of vessels within 10 km from substrata (P=0.011).

This result is likely a combination of several factors, as detailed for the effect of distance from a single vessel above, but also sparse data available in the presence of 2+ vessels, especially in group behaviour and composition data (40 cases, compared to 113 cases in RAD data).

In summary, none of the analyses had sufficient power to detect an effect of 2+ vessels relative to the effect of a single vessel at effect sizes of <50% reduction or increase, and several analyses did not have sufficient power to detect effect sizes up to -100% or +300%. As additional data are collected, and especially if the spatial extent of exposure to vessels is reduced further from the current 10 km limit, it is expected that statistical power would increase.

Table 1: Power to detect effects of distance from a single vessel

Analysis	Effect size for power ≥0.8 (%)	Range of observed effect sizes at 0 km (%)	Effect detected in original analysis?
RAD	-65% or +85%	-55% to +82%	Y
Group size	-35 or +45%	-11% to +27%	N
Group composition – presence of calves or yearlings	-70% or +100%	-4% to +6,694%	Y
Group spread	-80% or +170%	-93% to +11%	N
Group formation	-90% or +160%	-87% to -58%	N, but noted potential effect based on effect size
Group direction	-95%	+1,891% to +3,171%	Y
Travel speed	-90% or +200%	-76% to -11%	N
Distance from Bruce Head shore	-90% or + 200%	-98% to -34%	Y

Table 2: Power to detect effect of presence of multiple vessels within 10 km from narwhal

Analysis	Effect size for power ≥0.8 (%)	Observed effect size (%)	Effect detected in original analysis?
RAD	-70% or +100%	27%	Y
Group size	-55% or +92%	+32%	N
Group composition – presence of calves or yearlings	-50% or +210%	+11%	N
Group spread	+250%	+108%	N
Group formation	None of the effect sizes examined	-2%	N
Group direction	None of the effect sizes examined	+287%	N
Travel speed	None of the effect sizes examined	-4%	N
Distance from Bruce Head shore	+50%	-89%	N

APPENDIX F

End of Season Interviews with Inuit Participants

General Program

1. What was your experience working at Bruce Head this summer? Overall, was your experience positive?
    - Good, positive overall.

2. Would you like to see the Bruce Head Program continue in the future?
    - Yes.

3. What changes, if any, would you like to see to the Program in the future? (e.g. program design, camp accommodation, camp rules, communication, duties, etc.)
    - Paper datasheets get blown away too easily.
    - Possible computer data entry but it's not always the best option either – for herding events paper is better – can write 2+ sightings at once vs entering data in the computer.

    Camp

    - Overall, camp was alright.
    - Sometimes there were noise complaints.
    - Toilet was cold but better than another, more exposed set up. Toilet was dark – no light.
    - Tents – good.
    - Kitchen – good.
    - Polar bear monitors – consider rifle instead of shotgun, better range and shotguns pellets spread easily especially with the wind up there.
    - Electric fence – more likely to get shocked than to actually see a polar bear – not the best set up but glad that the fence didn't extend to the viewing platform
    - Curfews – alright, good to keep track of where everybody was,
    - Needs to be better communication at the start of the program – what can observers say or not say to hunters on the water. Observers told during the program that they couldn't pass on info.
    - Communication (outside) – good wifi (better than on the Botnica), sat phones and InReach were available to use if needed (emergency or otherwise).
    - Communication between Golder team and Observers was good.

4. What did you learn from working with the biologists at Bruce Head this summer?
    - Data collection protocol, i.e. group formations, speeds, behaviours, etc.

5. What do you think you taught the biologists working at Bruce Head this summer?
    - No specifics, too much to recall – everybody spoke a lot and shared a lot of information.

6. Did you feel valued/included/treated fairly by others at camp this summer?
    - Yes, overall.
    - Times when Observers weren't part of all of the discussions with Golder crew.
    - One specific Golder person was causing some tension within the group by taking photos of Observers at work (when they didn't know). They don't mind having photos taken but should be asked first, don't sneakily take photos.

Analysis of Narwhal Behaviour

1. What do you think is the best way to study narwhal behaviour?
   - The way we studied them from Bruce Head – also have to consider when narwhal are submerged, can't collect that data.
   - Drone also possibly good to get correction factor but needed more time, too short of a program this year and not many flights.

2. Do you think that this study could be expanded to other marine mammal species, other than narwhal?
   - Not sure.
   - Depends on the species – some animals are more shy than others. Caribou are shy. The mine site seems to be careful around caribou and have been observed keeping their distance from caribou herds if they are observed.
   - Could also observe bowhead and seals from Bruce Head.
   - Need better binoculars – especially if studying seals (more power), only 2 of the binoculars were used by the observers.

3. What do you expect to see if narwhal are exhibiting signs of stress or disturbance?
   - Dive longer.
   - Swim away from small boats (hunters), bigger ships have a different impact – when ship first approaches, they react like they do when hunted and then calm down once the ship has passed.

4. Do you think that narwhal are affected by shipping activities?
   - Yes, of course – not an easy question to answer right away. It needs more thought than in this conversation. Probably not seeing affects right now but they will become more apparent later.

5. If yes above, what activities related to shipping do you think have the greatest effect on narwhal?
   - Noise – they have sensitive hearing.
   - Presence of ship affect them too.
   - Ship's sonar – can be so strong they don't see whales anymore. For example, one Observer worked on a research ship that reported that once it upgraded its sonar and the ship's crew stopped seeing them.

6. At what distance do narwhal start reacting to the vessels? How long after a ship has passed does it take for them to return to the normal behaviour?
   - Don't know.
   - They are always affected no matter how far or close they are and depends on season – early they are more easily affected and late season they are less affected by shipping.
   - Narwhal move closer to shore early in the shipping season and then less affected later.

7. What areas on or near the shipping route do you think are most important for narwhal? Why?
   - Depends on season – when the ice is breaking up they're trying to move up inlets and then mid-summer they're in the Koluktoo Bay and Tremblay Sound calving grounds.

8. Do other factors (i.e. human activities or environmental conditions) affect narwhal behaviour?
    - Hunting – but it's been historically consistent while the shipping is new.

9. Did you see killer whales in the study area? How do narwhal react to killer whale? How does it differ from their reaction to ships?
    - Yes.
    - Narwhals are terrified of them – tightly hugging the shore, travel fast (scared).
    - Narwhal don't panic as much with ships.

10. What activity do you think creates the greatest change in marine mammal behaviour?
    - Hunting by humans.
    - Hunting by killer whales.

11. Why do narwhal swim close to the shore?
    - To feed, travel and hug shore to get to shallower water when scared – get away from predators, especially killer whales.

12. Why do narwhal change the direction of their travel?
    - Always on the move – will change direction when they have to keep traveling in the direction they're going.

13. Why do narwhal groups split up?
    - Mornings – individuals split up to relax and feed.
    - As day goes on – join into groups.

14. Why do narwhal change their speed of their travel?
    - Don't know – it depends.
    - Distractions.
    - Predators.

15. Why do narwhal seem to change their diving when ships are around?
    - Hard to say – we can only recognize a few of them. Hard to recognize which groups are diving, how long they're diving and if they change their diving behaviour.

16. Did you see anything during the program that you did not expect to see?
    - No.

<u>Reporting</u>

1. What is the best way to describe the studies that were undertaken at Bruce Head this year? (e.g. descriptive text, figures, photos, etc.)
    - Doesn't matter as long as the studies are properly shown to community and hunters – everybody wants answers to see how the narwhal are affected, not everyone in the community knew about the Bruce Head program and how the data is collected.

2. What is the best way to communicate results to the residents of Pond Inlet?
    - Through a meeting.

3. What do you think people are most interested in hearing about?
    - To see how they're affected by the shipping especially because the shipping is new and a lot of people don't like it.

4. What was most interesting to you?
    - To find out what the program was about specifically – didn't understand what observations were being done before participating in the program, learning how the data was collected.

Adaptive Management

1. Has your opinion of the impact of shipping activities on marine mammals changed since you participated in the program?
    - Have already seen how the narwhal are impacted before the program so no change in opinion.

2. Do you have any suggestions on how to improve monitoring of shipping effects on narwhal, or marine mammals in general?
    - Expensive option but with so many ships, why are we the only observers on a single vessel (Botnica) – would be better to have observers on each vessel, but we need to know the animal's behaviours to know how they change. Need more data over time.

In closing, the Observers were also asked if they agreed with this statement: "In the past, when a vessel would come by, the narwhals would dive in the water, disappear, and then head back to Koluktoo Bay before coming back a bit later. This year, some other observers are saying that they weren't seeing that, that the narwhals weren't really reacting as much to the vessels".

- Yes, they agree with this statement. Also one Observer provided an example from the Nanisivik area and that his grandfather observed the same in the past.

Any additional comments:

- Would be good to translate the questionnaire.

GOLDER

golder.com

Baffinland

Name: Marianne Marcoux, Jacquie Bastick

Agency / Organization: DFO/PCA

Date of Comment Submission: June 19th, 2020

#	Document Name	Section Reference	Comment	Baffinland Response
1	2019 Bruce Head Shore-based Monitoring Program	General comment	It would be useful to see results integrated with those from other Baffinland marine monitoring programs. For example, how do the responses of tagged narwhals compare with received sound levels from the PAM data? How do observations from Bruce Head compare to observations of narwhals tagged in the 2017-18 integrated tagging study? Or with CPA and behavioural data from the SBO program?	Comment noted. The various programs undertaken by Baffinland are designed to obtain a comprehensive understanding of narwhal response to vessel traffic. A Technical Memorandum entitled “Summary of Results for the 2019 Marine Mammal Monitoring Programs” was submitted to DFO in May 2020 and incorporated an integrated summary of the results of all the marine mammal monitoring programs. Results obtained from other studies (e.g. the 2017-2018 Narwhal Tagging Study) have helped to inform the study design for the Bruce Head Program. For example, the locations of the survey grids for the 2020 UAV (drone) program component at Bruce Head were informed by the surface movements of narwhal derived from the 2017/2018 tagging data. Baffinland will also be preparing a standalone technical report that will correlate visual and acoustic data collected on narwhal during the 2019 field season. This report will use data collected from the various studies (i.e. 2017-2018 Narwhal Tagging

Baffinland

#	Document Name	Section Reference	Comment	Baffinland Response
				Study, Bruce Head Shore-based monitoring, PAM) to inform the overall study design and an integrated interpretation of narwhal behavioral results.
2	2019 Bruce Head Shore-based Monitoring Program	Executive Summary- Relative Abundance and Distribution And 7.0 SUMMARY OF KEY FINDINGS Relative Abundance and Distribution	It is suggested that the year 2014 is used as a reference. However, according to table 5-2, there were 13 one-way transits recorded in 2014 during the study period. It might be more helpful to compare the number before any project related shipping occurred. In addition, given the variability in narwhal densities between years, it might be helpful to use an average as baseline instead of data from a single year.	Text in the report has been modified to account for a correction in the number of vessels reported in the SSA rather than in the RSA (the SSA is the study area relevant to the Bruce Head program). As noted in the report, only five Project-support vessels (i.e. cargo vessels) passed though the SSA in 2014 and none were carrying iron ore. The other 48 vessels present in the broader RSA (of which 13 transited through the SSA) were not Project-related. It is likely that a similar number of non-Project-related vessels were present in previous years, making it nearly impossible to assess relative abundance of narwhal in the complete absence of vessel traffic (Project-related or not). As such, Golder is of the opinion that it remains valid to consider data collected in 2014 as baseline for assessing relative abundance of narwhal within the SSA.
3	2019 Bruce Head Shore-based Monitoring Program	4.4.1.2. Automatic Identification System (AIS) data	BIM has changed the distance of “potential vessel effects” from 15 km to 10 km based on the *2017-2018 Integrated Narwhal Tagging Study - Technical Data Report data report.* However, in the tagging report, there is no test for the 15 km threshold. It might be worth investigating different distance thresholds.	The distance used to delineate exposure vs. non-exposure zones (i.e. 10 km) is supported by acoustic modeling conducted by JASCO in which the majority of the disturbance noise field falls within 10 km of the source (Quijano et al. 2017). Of note, the R95% values indicated a disturbance zone of between 5.93 and 11.20 km. Monitoring results collected to date as part of JASCO’s Passive Acoustic Monitoring (PAM) program suggest

#	Document Name	Section Reference	Comment	Baffinland Response
				that modelling estimates are conservative (i.e., the 120 dB disturbance zone is likely well under 10 km). Furthermore, the behavioral threshold commonly referred to in the literature is not weighted to account for the frequency range in which marine mammals are sensitive to hearing. As the majority of underwater sound generated by vessel traffic is concentrated below 200 Hz (Veirs et al. 2016), which is well below the assumed peak hearing sensitivity of narwhal (>1 kHz), accounting for species-specific hearing sensitivity would likely decrease the 10 km distance associated with the disturbance zone rather than increase it. The 10 km cut-off distance is further supported by other available marine mammal research including a review of sonar and seismic survey marine mammal monitoring literature, in which no significant behavioural reactions by toothed whales (excluding beaked whales and harbour porpoise) have been observed beyond several kilometers (Stone and Tasker 2006; Weir 2008; Southall et al 2014; Finneran et al. 2017). Based on this body of research, the US Navy uses a 10 km cutoff distance for limiting assessment of significant behavioural reactions for sonar emissions on toothed whales (Finneran et al 2017). As sonar and seismic noise sources are considerably louder than vessel noise, marine mammals are considerably more responsive to these types of sound sources than

#	Document Name	Section Reference	Comment	Baffinland Response
				they are to vessel noise. If toothed whale responses to sonar or seismic are deemed to be insignificant beyond 10 km, it is reasonable to assume that the same would apply for toothed whale responses to vessel noise (i.e. 10 km would be conservative in this sense). Therefore, as stated in the report and further supported by existing literature and passive acoustic monitoring results from 2018 and 2019, 10 km is likely an overestimate of the disturbance zone for narwhal. Should different distance thresholds be examined in the future, distances of interest would be those less than 10 km rather than greater than 10 km.
4	2019 Bruce Head Shore-based Monitoring Program	4.4.1.8 Data Filtering	It is mentioned that cases with 200 or more narwhal within substratum (3 cases) and cases where group size was <20 narwhal (18 cases) were removed. Do you believe these data points are accurate or are they the result of observer error? If they are real, would it be possible to use a different distribution (data transformation) in your models to accommodate for large data points?	For the RAD analysis, 3 cases were removed (with counts ≥200) out of a total of 32,4666 cases, which represents 0.009% of the data. For the analysis of behavioural data, where cases with group sizes >20 were removed (18 cases out of a total of 5,025 cases), the omitted cases accounted for 0.36% of the data. We assume that these cases were accurate and thus removed them as they were affecting model fitting. The objective of the analyses was to capture the effect of shipping on the overall narwhal population present around Bruce Head. Since these cases represent very rare events, including them in the analysis would reduce our ability to capture the effects of primary interest.

Baffinland

#	Document Name	Section Reference	Comment	Baffinland Response
	2019 Bruce Head Shore-based Monitoring Program	4.4.2.3 Relative Abundance and Distribution	Can you provide more detail about the spatial auto-correlation structure?	Text regarding the spatial auto-correlation structure has been added to section 4.4.2.3.
	2019 Bruce Head Shore-based Monitoring Program	5.2.1 Baffinland Vessels and Other Large/Medium-Sized Vessels Table 5-2	50% of the 1-way vessel transits were recorded by observers during the Bruce Head survey period. Would it be possible to increase the percentage of transits observed? It would be beneficial to observe during the entire shipping season to see if there are different impacts at the beginning and end of the season (e.g.: during icebreaking) than only during open-water season.	Baffinland aims to increase the percentage of vessel transits observed by MMOs during active observation shifts at Bruce Head. This will be done by closely tracking vessel movements via the shore-based AIS system and, wherever possible, observation shifts will be timed to overlap with incoming/outgoing vessels. Due to logistical constraints of maintaining an operational camp (e.g. colder temperatures causing water lines to freeze, etc.), the field program cannot be extended longer to capture the entire shipping season.
	2019 Bruce Head Shore-based Monitoring Program	7.0 SUMMARY OF KEY FINDINGS	As mentioned in the comment below, it would be helpful to include some information about the power analysis here to help interpret non-significant results.	Comment noted. Text in the summary has been updated to include more information on the power analysis.
	2019 Bruce Head Shore-based Monitoring Program	Appendix E. Power Analysis	The power analyses are helpful to put the results in perspective. For example, with the current data, it is very difficult to detect changes in narwhal abundance related to the change in number of vessels from one to more than one. For some analyses, the data was not sufficient to detect any effect. Tables 1 and 2 are great tools to understand and interpret the analysis. We encourage BIM to produce these types of power analysis in the future. In addition, it	Comment noted. Similar tables will be provided in monitoring reports going forward. However, tables will remain in the appendix in an effort to avoid redundancy in reporting.

#	Document Name	Section Reference	Comment	Baffinland Response
			would be helpful to include Tables 1 and 2 in the main document.	

Baffinland

Name: Amanda Joynt

Agency / Organization: Oceans North

Date of Comment Submission: June 15, 2020

#	Document Name	Section Reference	Comment	Baffinland Response
1	Draft 2019 Bruce Head Shore-based Monitoring Report	1. Increased instance of narwhal travel following ship southbound transit when vessels at range 1-3 km (p.82) 2. More likely to be in tight group spread when vessels 3-4 km away in BSA (p.75) 3. Increased probability of slow swimming when vessel 2-3 km S of behavioral study area (BSA; p.88) 4. Lower probability of observing slow swimming groups when vessels at range 2-3 km N of BSA (p.88) 5. Decreased distance from shore when vessels within 3 km (p.94) 6. Larger probability of observing groups nearer to shore when vessels transiting toward the BSA	Clarify for each of these ranges, what is the range of distance to the animal. The behavioral study area (BSA) is about 1km wide, there is a generalization made that impact across the BSA is the same. Would a reported range of 1-3km between ship and the BSA for a particular behavioral response translate to a range of 1-4 km between the ship and the animal? This information is important to estimate the received sound levels corresponding to the reported radii of impact around the ship.	It is acknowledged that the large size of the substrata (and the BSA) means that while the effect is estimated based on distance to the centroid of the substrata (or the BSA), the individual animals within the substrata would likely experience different received levels with varying disturbance effects. However, without specific coordinates for each individual group sighting, it is not currently possible to refine this approach. For the 2020 Bruce Head Monitoring Program, drones will be used to monitor narwhal groups, which will ultimately provide specific coordinates of individual groups and allow for more precise calculation of distances from vessels. Of note, more precise locations of narwhal groups will be documented via the UAV in focal follow surveys near Koluktoo and in UAV surveys of narwhal near the AMAR. Assessment of received noise levels and associated changes in behavior will be evaluated as part of a Vocal-Acoustic Correlation (VAC) analysis that will consider

#	Document Name	Section Reference	Comment	Baffinland Response
				changes in narwhal vocal behaviour in relation to vessel distance.
2	Draft 2019 Bruce Head Shore-based Monitoring Report	Page 32	In terms of the Southall *et al*. (2007) ranking of the severity of behavioral responses to underwater noise (p.450, Table 4), each of these behavioural changes has a score that fits into the noise impact framework proposed by the proponent. What are the specific behavioral response severity scores assessed by the proponent for the observed responses? For each response, what were the post-exposure times observed for re-establishing post-exposure behavior?	Narwhal behavioural responses (i.e., change in relative abundance, changes in group direction, change in distance from shore) that were shown to be significantly influenced by vessel noise or close vessel encounters corresponded with severity scores ranging from 1 to 4. Narwhal demonstrated a return to pre-response behavior shortly following the exposure event (and within the time frame the vessel would have been audible to the animal). For example, vessel exposure was shown to result in a significant decrease in narwhal sightings in the SSA compared to when no vessels were present, but only when narwhal were exposed to vessels travelling north and away from the SSA, and only at close exposure distances of 2-3 km. Assuming an ore carrier transit speed of 9 knots (16.7 km/h) in the RSA, the acoustic exposure period associated with this response would be 22 minutes per vessel transit. This nature of response was considered short-term as it did not persist beyond the vessel exposure period (consistent with the time period an animal would occur within the 120 dB exposure zone of a transiting

Baffinland

#	Document Name	Section Reference	Comment	Baffinland Response
				vessel).
3	Draft 2019 Bruce Head Shore-based Monitoring Report	Page 78	In previous reports, the stratified study area would suggest there is a longer range behavioural response. And in this study, the maximum distance for responses is 4km – were there no behavioral responses to ship noise observed past 4km?	In the 2014-2017 Bruce Head Shore-based Monitoring Report (Golder 2019), RAD data suggested effects occurred within 10 km, and not at longer distances. The decision to decrease the spatial extent from 15 km to 10 km was based on an integrated review of the results from the 2014-2017 Bruce Head Shore-based Monitoring Program, the 2017-2018 Narwhal Tagging Study (Golder 2020) and the Passive Acoustic Monitoring Program (JASCO 2020). Significant behavioral responses observed in the Bruce Head study and the in the 2017-2018 Narwhal Tagging Study occurred at relatively restricted spatial extents (at closer distances than those corresponding with the 120 dB disturbance zone).

Baffinland

Name: Jeff W. Higdon

Agency / Organization: Qikiqtani Inuit Association

Date of Comment Submission: 16 June 2020

#	Document Name	Section Reference	Comment	Baffinland Response
1	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	1.1 Project Background, p. 18	Typo re: Production Increase - "... was approved for 2018 20 2021..." The summary of ore shipped and vessel numbers skips 2016 (has information for 2015, 2017-2019).	Typo noted and corrected in text.
2	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	1.3.1 Stratified Study Area (SSA), p. 21; Appendix A	Re: the addition of strata in 2020, Appendix A (Training Manual) notes that the precise boundary of strata J and K could be modified once at site and that it was expected that the western boundary of stratum K would be updated. The main document figure only shows stratum J, but the figure in the Training Manual included K and J. Stratum K was presumably removed once at the field site?	The training manual was prepared prior to the field team mobilizing to site. Once at camp, it was determined that strata K and L were beyond a reasonable line of sight and only stratum J was retained. This is reflected in the main document which was prepared following the field season. Going forward, only stratum J will be included in the SSA, together with the previously surveyed strata (A-I).

#	Document Name	Section Reference	Comment	Baffinland Response
3	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	2.5.2 Subsurface Movements (Dive Behaviour), pp. 28-29	How are diving and response data from the tagging work integrated into the overall adaptive management and mitigation strategy?	If significant behavioural responses are observed (those exceeding levels predicted in the impact assessment or those likely to result in population level effects), this would trigger a need to evaluate and consider adoption of adaptive management measures. Based on results of the 2017-2018 Tagging Data, a need for these actions has not yet been identified.
4	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.1 Study Team and Training, p. 37	Was all training conducted at site, i.e., none in Mittimatalik? How many Inuit with past experience from this project worked there in 2019? How many Inuit total?	Yes, all training was conducted at site. Two Inuit participants that had previous experience on the programs served as Inuit Leads in 2019. A total of 12 Inuit researchers participated in the 2019 program.
5	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.2.6 Acoustic Data, p. 43	"Detailed results from the Passive Acoustic Monitoring (PAM) Program are presented in Frouin-Mouy et al. (2020)." A lot of relevant acoustic data was not reported in the PAM report draft. For example, there was little information on noise characteristics from different vessel types (ore carrier, fuel tanker, etc.), or on the effects of vessel speed on noise characteristics. How will these extensive PAM data on vessel noise characteristics be integrated into the overall monitoring program?	Detailed analysis of individual sound signatures for each Project vessel was beyond the scope of the 2019 PAM Program data summary report. Analysis of these data is ongoing to determine more refined characterization of individual vessels and these results will be provided as they become available. Additionally, a graduate student from the University of New Brunswick is also undertaking a more detailed analysis of the received sound levels for individual transits of all Project vessels and a comparison of the relative sound levels emitted

#	Document Name	Section Reference	Comment	Baffinland Response
				from each. Results from those studies will be available in 2021.
6	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.1.4 Group Composition and Behavioural Data, p. 47	"Note that the BSA centroid used for 2014-2016 data differed from the centroid used for 2017 and 2019 data, as detailed in Section 4.4.1.1." That section (4.4.1.1, p. 44) discusses some changes but doesn't specifically mention the centroid location (the word "centroid" doesn't appear in that section).	Noted. Text added to Section 4.4.1.1 to detail the change in centroid location.
7	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.1.7 Acoustic Data, p. 48	"The alternative and preferred analysis approach was to visually assess the recordings using Kaleidoscope Pro and manually note the times of gunshot events. The gunshot events were readily identifiable during visual assessment (Figure)." Was the AMAR data also used to look for gunshot events? Was the entire 2019 recording period visually examined, or a subset? Also note that figure number is missing from the cited sentence.	Gun shots were evident in the AMAR data but were not examined in detail as the land-based acoustic recorder captured hunting events adequately, making analysis of both datasets redundant. Figure number has been added in report.

#	Document Name	Section Reference	Comment	Baffinland Response
8	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.2.1 Updates to Analytical Approach, p. 49-50	"Presence of multiple vessels within the spatial extent of effect (10 km) was incorporated into the model. While in previous analyses, cases with multiple vessels in the spatial extent of effect were removed from analysis, the analyses presented in this report were applied to the full dataset. To accommodate this change, specific vessel-related variables (distance, relative position, and direction within Milne Inlet) were set to describe the vessel that were nearest to the SSA / BSA, and the variable that previously was coded to identify whether vessels were present or absent was recorded, to describe whether there were no vessels, where there was a single vessel, or two or more vessels within the spatial extent of effect. Given that 2019 represents the first year that these analyses were undertaken, no comparison to past years for this dataset are presented." This isn't clear. If "[t]hese changes were applied to the entire five-year dataset, and therefore do not affect the ability to assess differences between sampling years" (p. 49), why was "no comparison to past years for this dataset… presented"?	The intent of this text was to underline that this was not performed previously, therefore there are no results that were presented in previous reports that the new, 2014-2019 results could not be compared to. The sentence has been removed based on comment provided by the reviewer.

#	Document Name	Section Reference	Comment	Baffinland Response
9	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.2.1 Updates to Analytical Approach, p. 49-50; 6.1 Relative Abundance and Distribution, p. 121	"Vessel effects were considered when vessels were within 10 km from SSA and BSA centroids, as opposed to the 15 km spatial extent that was used previously, as detailed in Section 4.4.1.2." "It is possible that the spatial extent of the effect of vessels does not cover the full 10 km modeled, as was found in the analysis of dive and movement behaviour of narwhal equipped with GPS and dive tags (Golder 2020a). In this case, it is likely that the model overestimated narwhal counts in the vicinity of vessels, to better fit counts farther from the vessel (where the effect from vessel traffic is likely smaller)." Some sensitivity analysis on the influence of the distance chosen would be instructive.	A sensitivity analysis may be conducted on the distance selected with the integrated dataset moving forward.
10	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.2.2 Fixed Effect Predictors, p. 50	"The plot provided a visual tool to identify potential trends in the response variable in relation to vessel predictor variables." Some example plots would be useful to visualize what was done.	These plots are provided in each respective results section, as they are part of the presented results. For example, Figure 5-13 for RAD analysis (Section 5.3.1)

#	Document Name	Section Reference	Comment	Baffinland Response
11	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.2.2 Fixed Effect Predictors, p. 50-51	Were variable combinations examined for colinearity issues?	Yes, generalized variance inflation factors (GVIFs; Fox and Monette 1991, Weisberg and Fox 2011) were calculated for each model, where GVIFs > 3 indicated collinearity (Zuur et al., 2010). For all models, all GVIF values (adjusted for number of coefficients for polynomial and categorical variables; Weisberg and Fox 2011) were <3. Fox, J. and Monette, G. (1992) Generalized collinearity diagnostics. JASA, 87, 178–183 Weisberg, S. and Fox, J. (2011). An R Companion to Applied Regression. (2 ed.) Thousand Oaks: Sage. http://socserv.mcmaster.ca/jfox/Books/Companion/index.html Zuur A.F., Ieno E.N, and Elphic C.S. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1:3–14
12	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	4.4.2.4 Group Composition and Behaviour, p. 53	To clarify, any/all groups with at least one “unknown” stage individual were classed as “other”?	That is correct.

#	Document Name	Section Reference	Comment	Baffinland Response
13	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.2.3 Other Anthropogenic Activities, p. 66	"Important to note, however, is that monitoring of hunting activity for the full extent of the day (i.e. 24 h) only occurred in 2019 with the introduction of a pair of Wildlife Acoustics SM4 acoustic recorders…" Will the SM4 recorders be used for 2020 and future years?	Yes.
14	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.3.1 RAD Modeling, p. 75 (and a general comment re: findings)	How do these findings contribute to the development of adaptive management plans and mitigation opportunities, should they be required? How do the results, specifically the differences related to transit direction, compare with results from other monitoring programs (e.g., PAM recordings of vessels) and IQ?	If significant behavioural responses are observed (those exceeding levels predicted in the impact assessment or those likely to result in population level effects), this would trigger specific response actions by Baffinland which may include enhanced monitoring and/or additional mitigation measures. Behavioral responses observed in the Bruce Head study occurred at relatively restricted spatial extents (i.e. at closer distances than those corresponding with the predicted 120 dB disturbance zone; Quijano et al. 2017). Existing IQ studies do not provide specific distances at which observed responses occur, so a comparison of the present response distances observed to available IQ is not straightforward. If QIA has additional IQ to share that details specific distances in which responses occur, we would be pleased to review and consider this information as it is provided.

#	Document Name	Section Reference	Comment	Baffinland Response
15	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.4.1 Group Size, p. 86	Re: Figure 5-19, mean and median group sizes could be added to the plots.	Noted. Values added to figure.
16	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.4.2.1 Presence of Tusks, p. 92	"In summary, the analysis of tusk presence using 2014–2017 and 2019 integrated Bruce Head data supports rejection of the null hypothesis that presence of narwhal with tusks (i.e., groups comprised of mature males) does not significantly change during vessel-exposure events." The presence of a tusk doesn't necessarily mean the animal is a mature male, as the tusk is growing well before males reach sexual or physical maturity. How long does a tusk have to be before it can be reliably identified from the monitoring station?	In agreement with this comment. Upon further consideration of the biological relevance of including the analysis of presence of tusks (section 5.4.2.1), this analysis was removed from the 2019 report. Future analyses will focus on adult groups specifically (whether with or without tusks) relative to groups possessing immature animals. This would allow for evaluating whether groups of different composition show different response strategies based on their potential to actively avoid or maneuver away from vessels (i.e., immatures may be less capable to actively avoid vessels). Depending on the sighting conditions at the time and the movements of the animals, even very small tusks on juveniles can be reliably identified from the vantage point of the monitoring station.
17	2019 Bruce Head Shore-based Monitoring Program - Mary	5.4.2.2 Presence of Calves or Yearlings, p. 94	In the analysis of the presence of calves or yearlings, groups that consisted of a single narwhal were removed, to avoid	Solitary calves or yearlings were observed nine times in 2019, twice in 2017, and five times in 2016.

#	Document Name	Section Reference	Comment	Baffinland Response
	River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)		skewing the analysis results because calves or yearlings were assumed to never be solitary. Are there any observations of solitary calves (in all years) made from the Bruce Head program? There was one in the aerial survey dataset. What IQ is available on the presence of solitary calves?	We are unaware of any reports or incidences of solitary calves based on available IQ information. If QIA has additional IQ to share on the presence of solitary calves, Golder would be pleased to review and consider this information as it's provided.
18	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.4.7 Distance from Bruce Head Shore, p. 115	Re: Figure 5-40, what factors lead to unknown (i.e., missing) distance records, equipment malfunctions, human error, etc?	Text added to results describing Figure 5-40, as well to results describing similar graphs for the other sections on behaviour and composition
19	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.5.1 Other Marine Mammals, p. 120	"On 18 August 2019, a pod of eight orca whales (*Orcinus orca*) were observed travelling south through the SSA (substrata A1, A2, A3, B2, C3, D2, and E2)." How did narwhal react to killer whale presence? The effects of predator presence are an important consideration for effects monitoring.	As suggested in the literature (Breed et al. 2017), narwhal responded to the presence of killer whales in the area by travelling at high speed to the shore, then once reaching the shore, animals travelled very slowly and close to shore. This response was particularly noteworthy given that hunting vessels were present at the shoreline of the BSA at the time and would normally cause narwhal to dive down or avoid the shoreline altogether, but in this case, the narwhal froze near the surface very close to shore and in proximity to the visible hunters.

#	Document Name	Section Reference	Comment	Baffinland Response
20	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.1 Relative Abundance and Distribution, p. 121	"The results of the combined 2014–2017 and 2019 analysis are mostly similar to the result of the analysis of the combined 2014-2017 dataset (Golder 2019), with the main difference being that in the current analysis, the relative direction of the vessel (i.e., whether it was heading toward or away from substrata) was found to be a significant predictor. While the analysis of the 2014-2016 dataset (Smith et al. 2017) found that narwhal counts were significantly different when northbound vessels were heading away from a substratum than in all other scenarios, this was not the case in the current analysis." Additional data now being available is one obvious difference, but what changes to model structure, parameter definitions, etc. need to be considered when interpreting these contrasting results?	Text was added to the section to clarify the likely cause of the differences.
21	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.2.4 Group Formation, p. 123	"... further monitoring of narwhal group formation is warranted to better understand whether a given formation is indicative of a potential response to a perceived threat (i.e. a transiting vessel)." Could aerial photos (from the survey) be used as a data set here, for further integration of	Imagery collected by the UAV during the 2020 Bruce Head Program will be used to inform narwhal group formation.

#	Document Name	Section Reference	Comment	Baffinland Response
			results from the various programs?	
22	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.1 Relative Abundance and Distribution, p. 121 (also 8.0 RECOMMENDATIONS, p. 128)	"It is possible that the difference in narwhal response to north- and southbound vessels is due to the difference in vessel noise propagation, combined with the spatial distribution of narwhal. Specifically, the noise output of northbound vessels propagates without an impediment throughout the opening of Koluktoo Bay and the southern strata of the SSA, where the majority of narwhal are usually located. Conversely, the noise of a southbound vessel north of Poirier Island is impeded by the Bruce Head peninsula, potentially resulting in a different response of narwhal in the southern strata and Koluktoo Bay." It would be useful to have additional monitoring in Koluktoo Bay, for example using a UAV. Additional analyses of the AMAR data are also warranted.	As part of the 2020 Bruce Head Program, a UAV will conduct surveys in the vicinity of AMAR 3 in order to inform vocal behavior of narwhal groups in relation to vessel traffic. Results of this work will be included in a standalone technical report (i.e., Visual-Acoustic Correlation (VAC) Study Report. The UAV will also conduct focal follows of narwhal at the mouth of Koluktoo Bay and throughout the SSA.

#	Document Name	Section Reference	Comment	Baffinland Response
23	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	5.4.2.1 Presence of Tusks, p. 92; 5.4.2.2 Presence of Calves or Yearlings, p. 95; 5.4.4 Group Formation, p. 103	Description/interpretation of statistical significance are inconsistent: in 5.4.2.1 a P-value of 0.056 is considered not significant, as is the same P-value in 5.4.2.2. However, in 5.4.4 (and in other draft reports), a P-value of 0.07 is considered "marginally significant".	In agreement with this comment. The variable should be considered "marginally significant" in 5.4.2.1. Text in the report has been edited to reflect this change.
24	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.0 DISCUSSION; 7.0 SUMMARY OF KEY FINDINGS	A table (or tables) would help succinctly summarize all the results. Some graphic descriptions of the differences in southbound vs northbound vessels would also be useful, particularly for community consultations	Based on the context required to discuss each response variable, the current format (i.e. bullet points summarizing each key finding) remains the preferred approach.
25	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.1 Relative Abundance and Distribution, p. 121	"These findings are consistent with results from Baffinland's other narwhal monitoring programs demonstrating that the Bruce Head area continues to support high narwhal concentrations and proportionately higher habitat use by narwhal compared to other areas in the RSA (Elliott et al. 2015; Thomas et al. 2015; Golder 2020a; Golder 2020b)." More explicit integration of results from all the different programs is needed to inform adaptive management.	Reference to the 2017-2017 Narwhal Tagging Program and the Aerial Survey Program have been added in the report to make the statement re: habitat use results more explicit.

Baffinland

#	Document Name	Section Reference	Comment	Baffinland Response
26	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	6.2 Group Composition and Behaviour, p. 122	Re: predation risk, this could be quantified to some extent based on the integrated monitoring data (killer whale visual and acoustic occurrence records) from the various programs	It is acknowledged that confounding effects such as predation events exist but they cannot be quantified directly given that this would require killer whales present in the area to also be outfitted with satellite tracking tags, which is logistically prohibitive. This is particularly true given that narwhal have been shown to react to the presence of killer whales at very long ranges (Breed et al. 2017).
27	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	8.0 RECOMMENDATIONS, p. 128	Re: the recommendation to "explore validating narwhal sightings data by imagery and/or video collected simultaneously via an UAV throughout the SSA" and "explore correlating narwhal sightings and UAV data with acoustic data collected in the vicinity of Bruce Head via AMARs to assess group-specific vocal behaviour relative to shipping activities", UAV surveys in Koluktoo Bay would be useful, particularly when combined with the acoustic data. This is important given the apparent differences in responses to northbound vs southbound transits.	Comment noted. The 2020 Bruce Head Program will incorporate both drone and acoustic components and attempt to correlate visual data collected via UAV with acoustic data collected via an AMAR deployed adjacent to Bruce Head.
28	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring	8.0 RECOMMENDATIONS, p. 128	"As more data are collected on narwhal group composition, behaviour, and RAD when in close proximity to vessels, it is recommended that the 10 km exposure zone be further restricted in order to better	See response to comment #9

#	Document Name	Section Reference	Comment	Baffinland Response
	Report_DRAFT FOR MEWG.pdf)		estimate vessel effects on narwhal at close distances”. Existing data could be used to explore the sensitivity of different zone descriptions using a subset of variables.	
29	2019 Bruce Head Shore-based Monitoring Program - Mary River Project, Baffin Island, Nunavut (file: 2019 Bruce Head Monitoring Report_DRAFT FOR MEWG.pdf)	8.0 RECOMMENDATIONS, p. 128	“... inclusion of hunting as a predictor in these models may not be beneficial, merits further discussion with the MEWG on whether to retain hunting as a predictor in the model moving forward.” Discussion with the MEWG is warranted, but this is also a conversation that needs to happen with hunters and elders in Mittimatalik. What data are available (published IQ, field studies, etc.) on how groups are selected and what factors influence the initiation of hunting events?	Based on previous field studies at Bruce Head, hunting efforts tend to focus on groups that are close to shore, especially if individuals within the group possess a tusk. Other factors such as narwhal exhibiting slow travel speed and extended surface time have appeared to contribute to the initiation of hunting events.